Science Mission Directorate

NASA Earth – Sun System Science

2004 Satellite Direct Readout Conference: A Decade in Transition
Miami, Florida

December 6, 2004

Lucia Tsaoussi, Ph.D.

Deputy Director Research & Analysis Program
Earth-Sun System Division


The NASA Vision
To improve life here,
To extend life to there,
To find life beyond.
The NASA Mission
To understand and protect our home planet,
To explore the universe and search for life,
To inspire the next generation of explorers
... as only NASA can.

New Space Exploration Vision

"This cause of exploration and discovery is not an option we choose; it is a desire written in the human heart." – President Bush

Background

After months of White House and NASA meetings, and exchanges of ideas and visions, a new comprehensive exploration vision has been developed

- **Given its importance, final decisions made by President**
- **Final decisions preceded successful *Spirit* landing on Mars**

New exploration vision builds on NASA's vision and mission statements

- **Other NASA activities remain an important element of NASA's mission such as aeronautics and climate change research**

New exploration vision enabled by NASA's progress in strengthening our management foundation and agency credibility

- **NASA received top scores in key areas of the President's Management Agenda**
- **NASA successfully implemented management reforms as demonstrated in key programs such as the International Space Station**
- **Other NASA programs continue to be successfully executed**

New Space Exploration Vision

On January 14, the President announced a new vision for NASA

- **Implement a sustained and affordable human and robotic program to explore the solar system and beyond;**
- **Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations;**
- **Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration; and**
- **Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests.**

The vision affirms the nation's commitment to space exploration and provides a clear direction for the civil space program

- **Vision responds to concerns expressed by the CAIB, Congress, and elsewhere on the need for a long-term vision for human space exploration**
- **Vision broader than some reports that it is about returning humans to Moon. Indeed, robotic activities and exploration of other destinations are critical elements**
- **Activities will be paced by experience, technology readiness, and affordability**
- **Implementation begins now with key missions that are already in progress such as Mars exploration, visits to other solar system targets, and Origins activities**

Transforming the NASA Organization

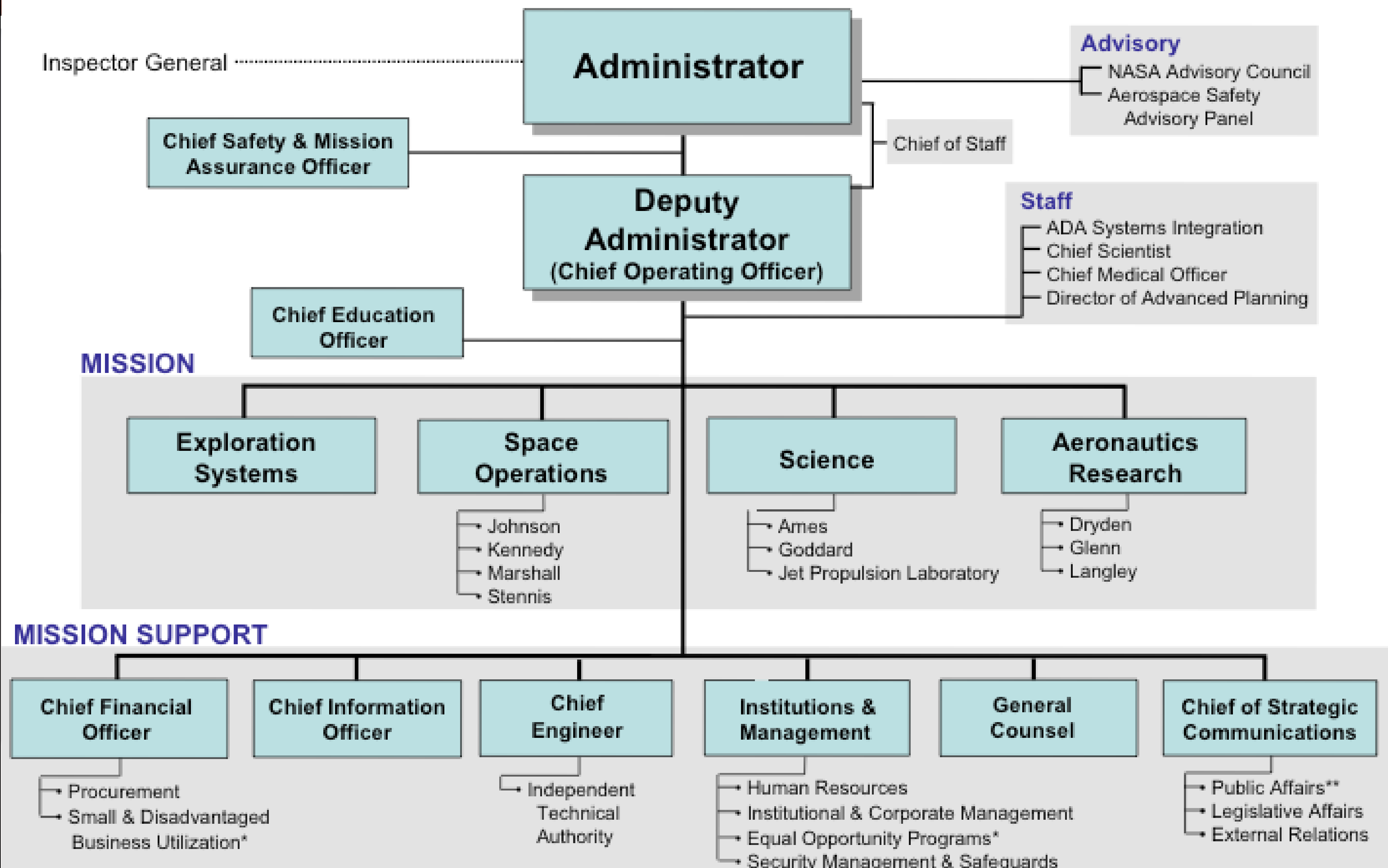
Restructured Mission Areas

- **Science** – Explore all of the planets in our Solar System, explore beyond our Solar System to understand the origins of the Universe and to search for life, provide science enabling human exploration of the most promising destinations.
- **Exploration Systems**-Design, research development, test and integration of systems in support of exploration.
- **Space Operations**-Human space flight operations and the operation of integrated systems in Low Earth orbit and beyond.
- **Aeronautics Research**-Research and development of aeronautical technologies that improve quality of life on Earth and enable exploration and discovery.

Improved Decision Making Processes

- **Strategic Planning Council**-Administrator chair, develops multi-year strategic plan, strategic roadmap, multi-year detailed plan that forms basis for budgets.
- **Chief Operating Officer Council**-Deputy Administrator chair, implements direction provided by Strategic Planning Council and develops standard administrative practices to build on President's Management Agenda.
- **Systems Integration**-Systems Associate Administrator responsible for system of systems integration across Mission Directorates.

Transformed Structure



** In accordance with law, the OEOP and SDBU maintain reporting relationships to the Deputy and the Administrator.*

*** Including a new emphasis on internal communications*

Revised:

Science Mission Directorate

Associate Administrator (AA) — A. Diaz

Deputy AA — G. Asrar

Deputy AA For Management — A. McNally

Deputy AA For Programs — O. Figueroa

__Councils__
- Leadership Council
- Science Management Council
- Program Management Council
- Operations Council

Education Officer

AAA/Strategy, Policy & Int'l
AAA/Science
AAA/Technology
AAA/Exploration Mission Int.
Sr. Policy Advisor

Mission Support

NASA Management Office — R. Parker

Administrative Processes — C. Sorrels

Mission

Earth-Sun System — M. Cleave (act.)

Solar System — A. Dantzler (act.)

Universe — A. Kinney

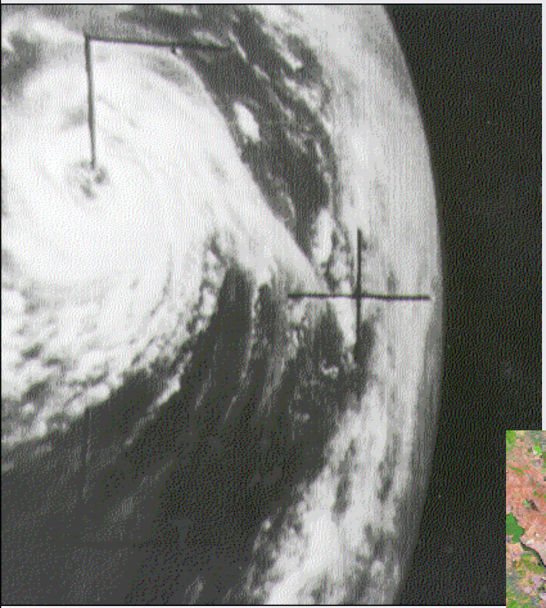
Mission Enabling

Business Management — R. Maizel

NASA Centers
- **JPL** — C. Elachi
- **GSFC** — E. Weiler
- **ARC** — S. Hubbard

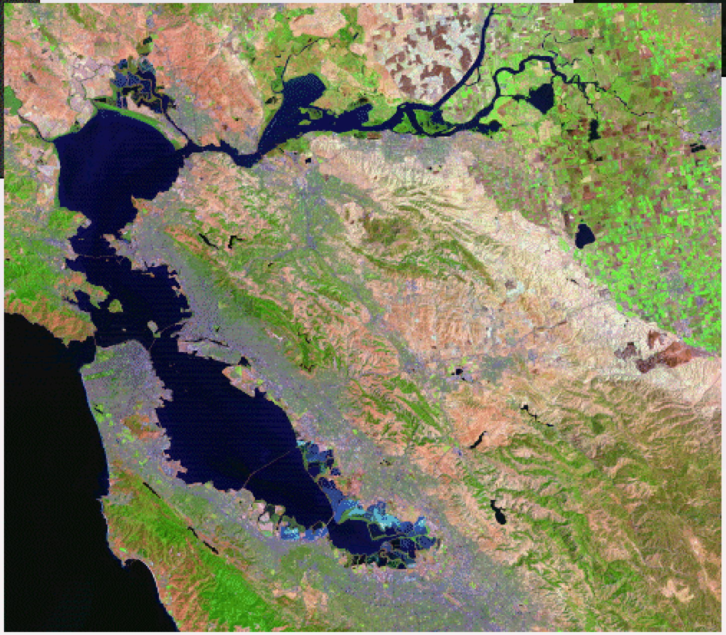
Mission & Systems Management — M. Luther

From the beginning, Earth Observation has helped answer science questions



TIROS VII Image of Hurricane Ginny, 1963

NIMBUS 7 (1978-94) provided data on sea ice extent, ocean color, sea surface temperature, radiation budget, and total column ozone



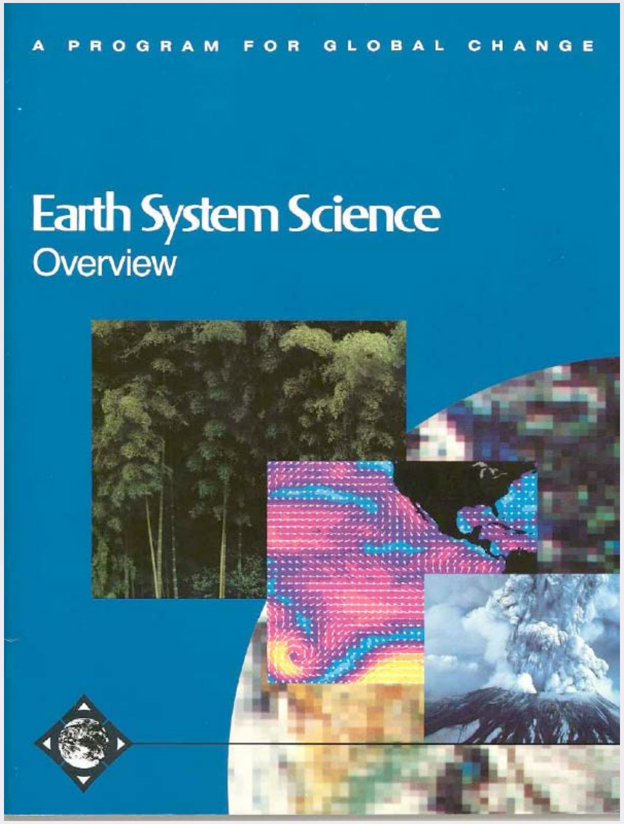
Landsat 4 (1984) Thematic Mapper image of San Francisco Bay

Seasat (1978) was the first radar satelite

The Rise of Earth System Science

"**The Goal of Earth System Science** -- To obtain a scientific understanding of the entire Earth system on a global scale by describing how its component parts and their interactions evolved, how they function, and how they may be expected to evolve on all time scales"

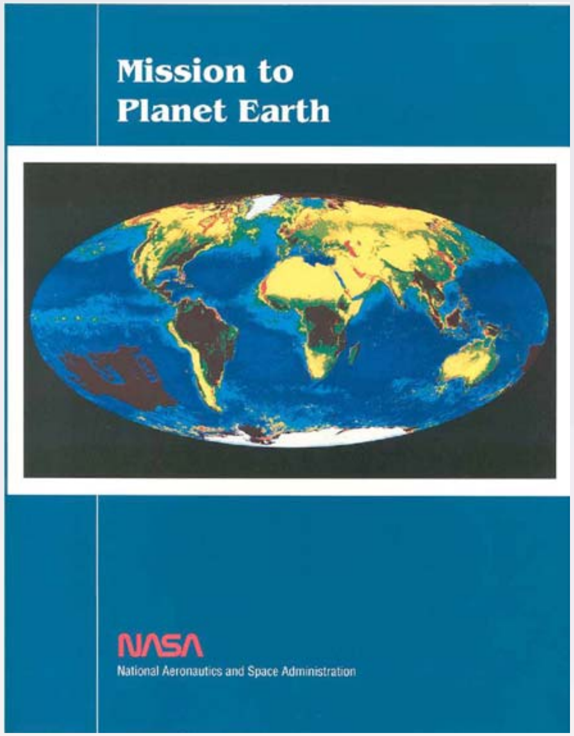
"**The Challenge of Earth System Science** -- To develop the capability to predict those changes that will occur in the next decade to century, both naturally and in response to human activities"



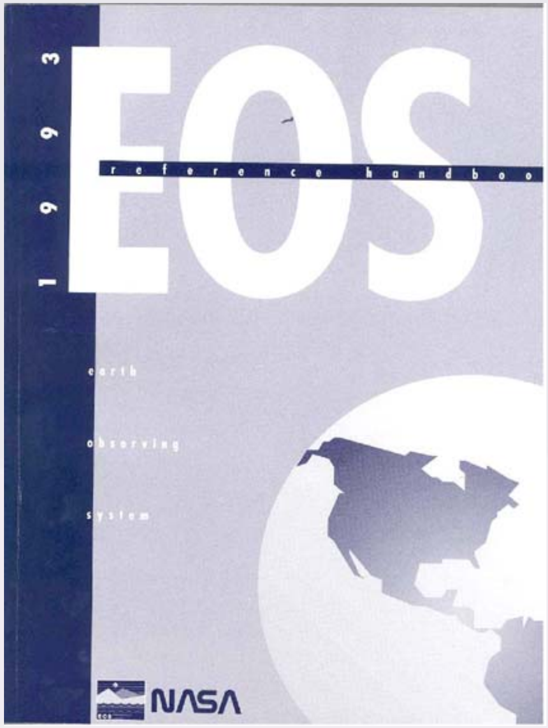
NASA Advisory Council
1986--88

From ESS to EOS

The Earth System Science concept resulted in the formulation of the Earth Observing System



The Earth Observing System was inaugurated as a Presidential Initiative in 1991



In the early/mid 90s, a series of design reviews led to the current multi-satellite configuration

Earth Science Research Fundamental Science Questions

How is the Earth changing and what are the consequences of life on Earth?

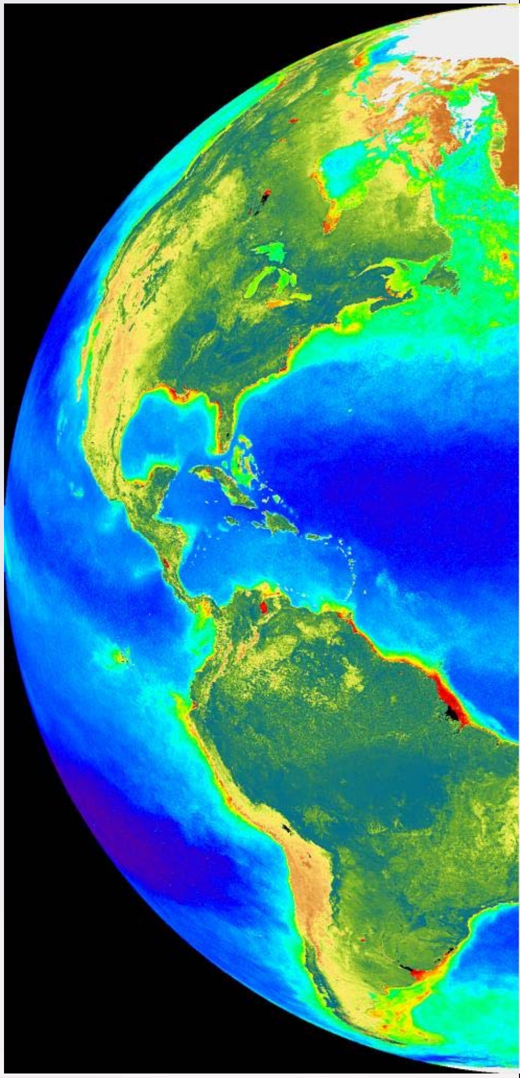
How is the global Earth system *changing*?

What are the primary *forcings* of the Earth system?

How does the Earth system *respond* to natural and human-induced changes?

What are the *consequences* of changes in the Earth system for human civilization?

How well can we *predict* future changes in the Earth system?



Science Questions and Focus Areas

Variability
- Precipitation, evaporation & cycling of water changing?
- Global ocean circulation varying?
- Global ecosystems changing?
- Atmospheric composition changing?
- Ice cover mass changing?
- Earth surface transformation?

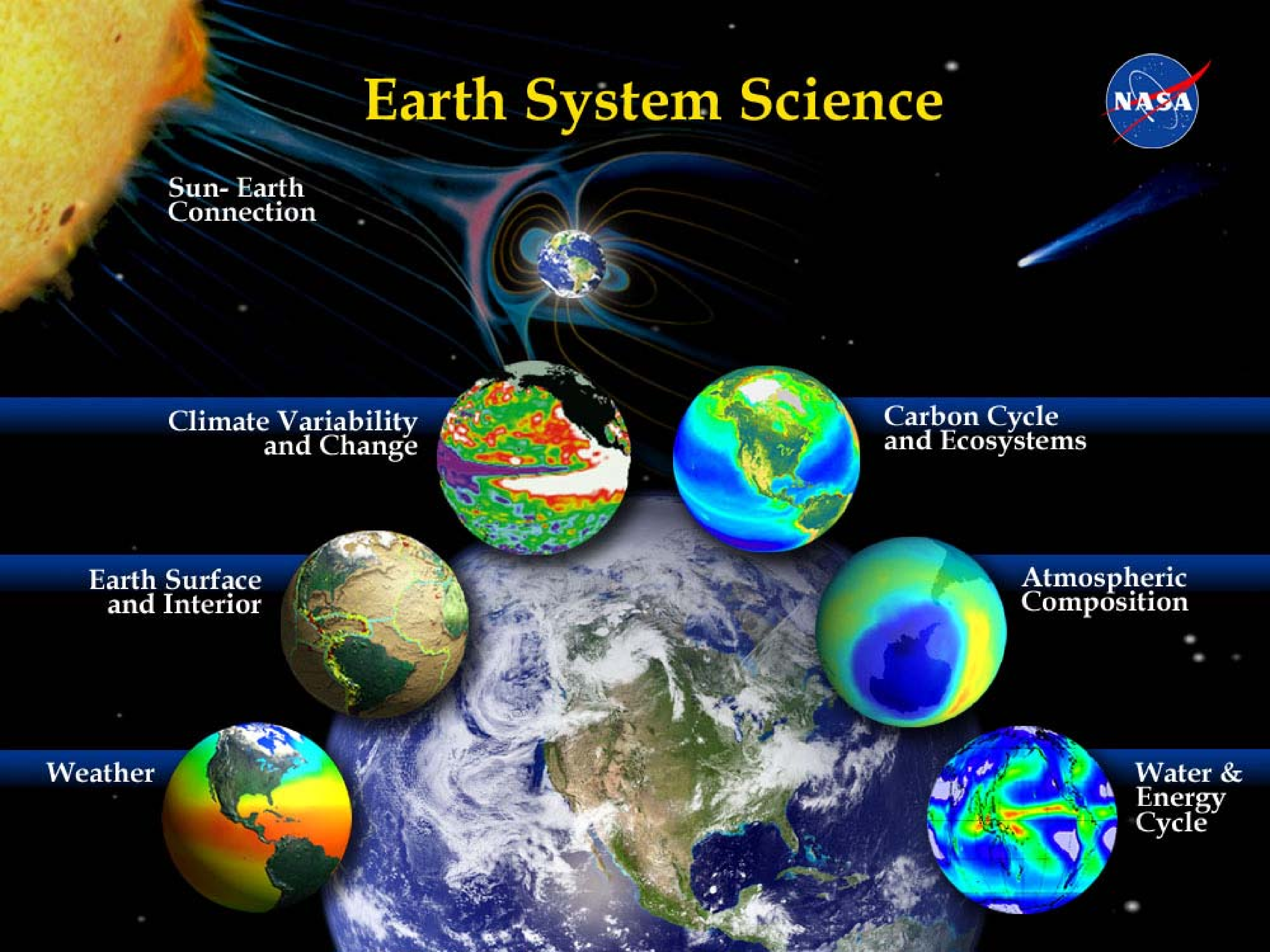
Forcing
- Atmospheric constituents & solar radiation on climate?
- Changes in land cover & land use?
- Motions of the Earth & Earth's interior?

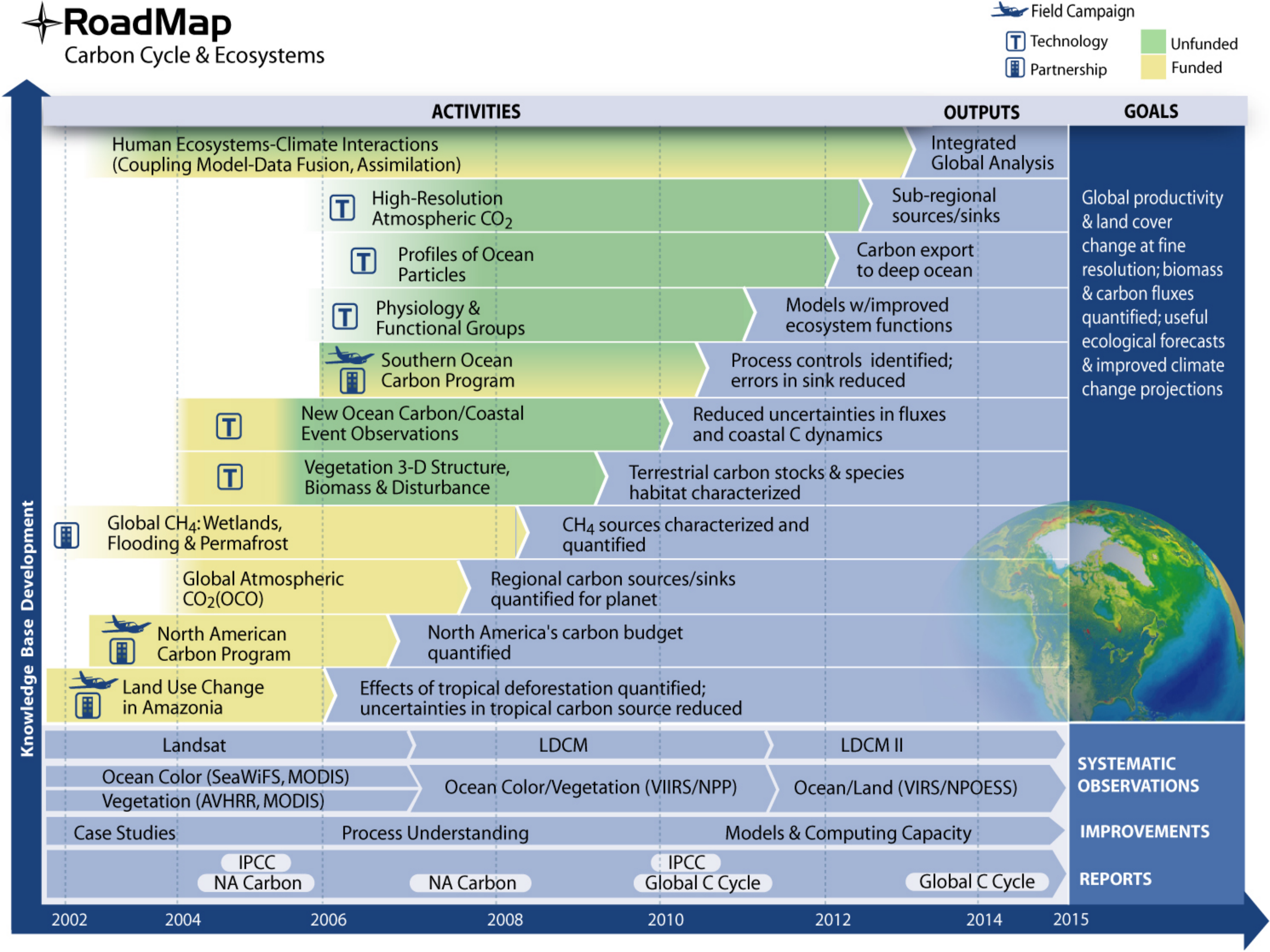
Response
- Clouds & surface hydrological processes on climate?
- Ecosystems, land cover & biogeochemical cycles?
- Changes in global ocean circulation?
- Atmospheric trace constituents responses?
- Sea level affected by Earth system change?

Consequence
- Weather variation related to climate variation?
- Consequences of land cover & land use change?
- Coastal region impacts?
- Regional air quality impacts?

Prediction
- Weather forecasting improvement?
- Improve prediction of climate variability & change?
- Ozone, climate & air quality impacts of atmospheric composition?
- Carbon cycle & ecosystem change?
- Change in water cycle dynamics?
- Predict & mitigate natural hazards from Earth surface change?

Climate Variability and Change
Carbon Cycle and Ecosystems
Water and Energy Cycle
Atmospheric Composition
Weather
Earth Surface and Interior


Earth System Science
NASA
Sun- Earth Connection
Climate Variability and Change
Carbon Cycle and Ecosystems
Earth Surface and Interior
Atmospheric Composition
Weather
Water & Energy Cycle


RoadMap
Carbon Cycle & Ecosystems
Field Campaign
Technology
Partnership
Unfunded
Funded
ACTIVITIES
OUTPUTS
GOALS
Human Ecosystems-Climate Interactions (Coupling Model-Data Fusion, Assimilation)
Integrated Global Analysis
High-Resolution Atmospheric CO_2
Sub-regional sources/sinks
Profiles of Ocean Particles
Carbon export to deep ocean
Physiology & Functional Groups
Models w/improved ecosystem functions
Southern Ocean Carbon Program
Process controls identified; errors in sink reduced
New Ocean Carbon/Coastal Event Observations
Reduced uncertainties in fluxes and coastal C dynamics
Vegetation 3-D Structure, Biomass & Disturbance
Terrestrial carbon stocks & species habitat characterized
Global CH_4: Wetlands, Flooding & Permafrost
CH_4 sources characterized and quantified
Global Atmospheric CO_2(OCO)
Regional carbon sources/sinks quantified for planet
North American Carbon Program
North America's carbon budget quantified
Land Use Change in Amazonia
Effects of tropical deforestation quantified; uncertainties in tropical carbon source reduced
Global productivity & land cover change at fine resolution; biomass & carbon fluxes quantified; useful ecological forecasts & improved climate change projections
Landsat
LDCM
LDCM II
Ocean Color (SeaWiFS, MODIS)
Vegetation (AVHRR, MODIS)
Ocean Color/Vegetation (VIIRS/NPP)
Ocean/Land (VIRS/NPOESS)
SYSTEMATIC OBSERVATIONS
Case Studies
Process Understanding
Models & Computing Capacity
IMPROVEMENTS
IPCC
NA Carbon
NA Carbon
IPCC
Global C Cycle
Global C Cycle
REPORTS
Knowledge Base Development
2002
2004
2006
2008
2010
2012
2014
2015

Atmospheric Composition

Stratosphere – Protects Life

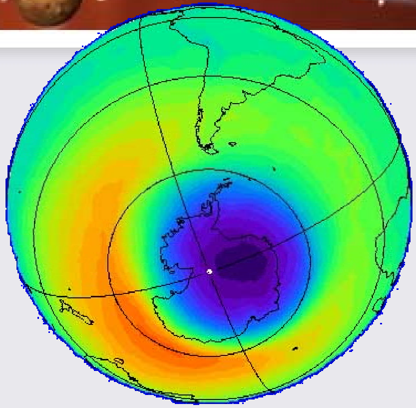
- Earth's UV-protecting ozone shield has decreased 6% globally since 1980
- Polar ozone loss (almost 50%) observed during spring seasons.
- The shield is continuing to change, driven in the future by a balance between periodic natural events (e.g. volcanoes), increasing human emissions, and controls on specific halogen-containing species

Troposphere – Sustains Life

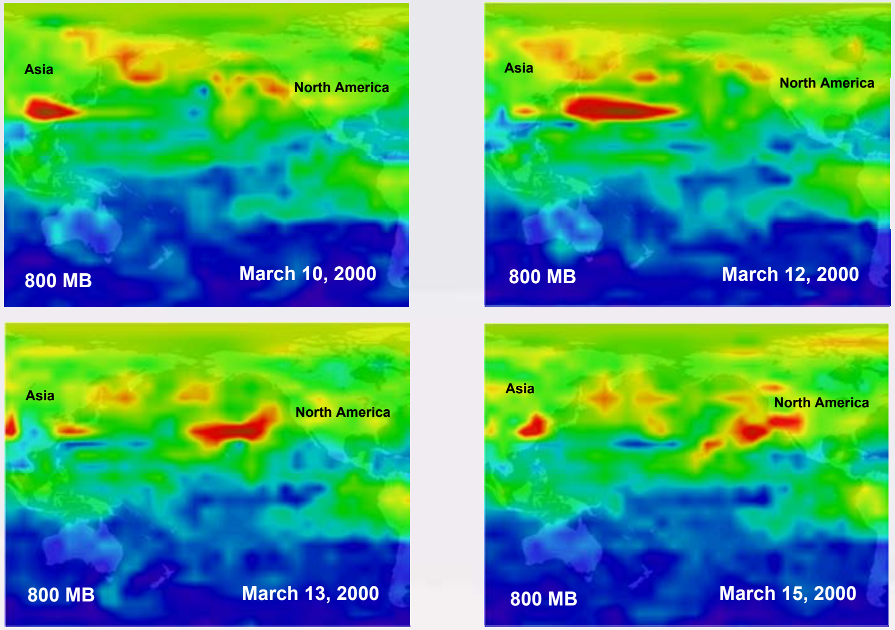
- Life on Earth depends on the clean air we breathe.
- Transport of non-US emissions and changing climatic conditions could become significant factors in determining air quality in various U.S. regions.

Climate – Supports Life

- The Earth's atmosphere has sustained life billions of years. What controls this unique condition?
- What are the consequences of changes in chemical transport, atmospheric composition and the hydrological cycle in controlling and maintaining a stable climate for the future?



2001 Antarctic ozone hole viewed by the TOMS satellite instrument



***Intercontinental Transport of Pollution*:**
Model assimilated CO data from the NASA EOS Terra satellite over the Pacific Basin (blue, a few parts per billion (ppb), red, polluted levels, of around 200 ppb)

Water and Energy Cycle

The global water cycle is resolved at only coarse resolutions, hampering climate models' ability to recreate hydrologic means and extremes that are relevant to local scales. Uncertainties in basic hydrological processes and in the strength of feedback processes, such as clouds and cloud processes, coupling of sea-ice-land, air-sea, and land surface effects result in large ranges in predictions of impacts to the overall climate system.

Water Cycle Study requires:

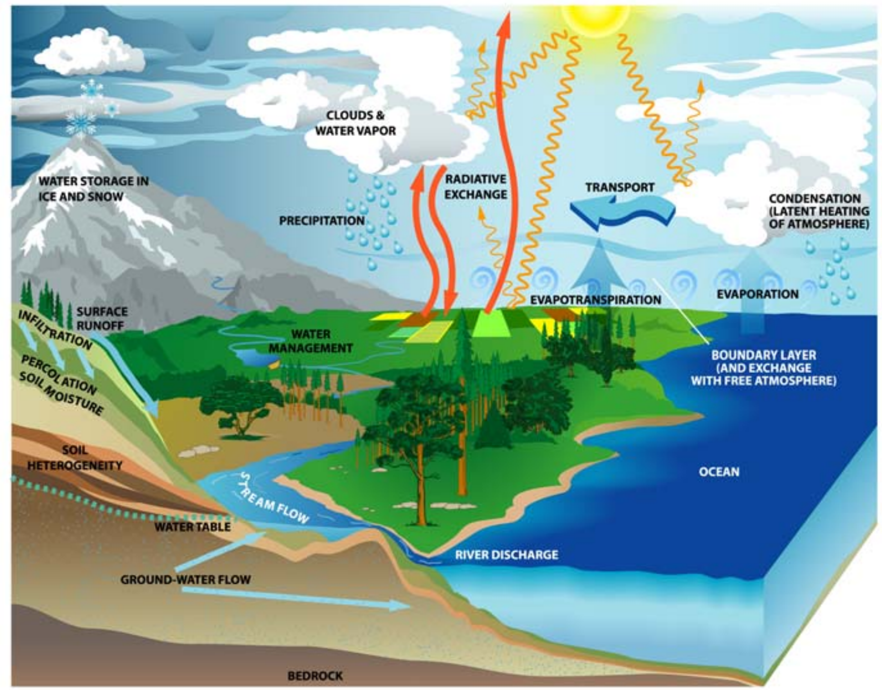
Land-atmosphere and ocean-atmosphere interactions partitioning of water and energy

Hydrologic states and fluxes: clouds, soil moisture, snow, precipitation, evaporation, etc.

Understanding the water cycle is important for:

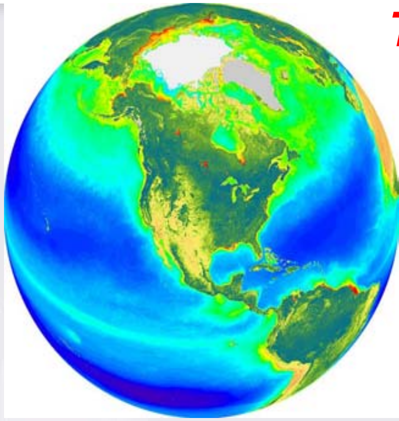
Water storage: Drinking Water, Water for Commerce and Energy

Linking Human Activity to Climate Change



NASA has a unique capability to provide global observations of the various components of the water cycle, and then use them to enhance global models and improve predictive capability

Carbon Cycle & Ecosystems



To understand and protect our home planet, **we must understand:**

- **the interactions of biogeochemical cycles and terrestrial & marine ecosystems with global environmental change and**
- **the implications for the Earth system**

Questions

- ***How are global ecosystems changing?***
- ***What changes are occurring in global land cover and land use, and what are their causes?***
- ***How do ecosystems, land cover and biogeochemical cycles respond to and affect global environmental change?***
- ***What are the consequences of land cover and land use change for human societies and the sustainability of ecosystems?***
- ***How will carbon cycle dynamics and terrestrial and marine ecosystems change in the future?***

Important Concerns:

- Greenhouse warming (CO_2, CH_4)
- Climate interactions
- Carbon management (C storage in plants, soils, & ocean)
- Productivity (food, fiber, fuel)
- Sustainability of ecosystem goods & services
- Biodiversity and invasive species

NASA provides the global perspective and a unique combination of interdisciplinary science, state-of-the-art modeling, and diverse synoptic observations

NASA Solid Earth

Goal

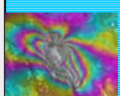
How is the Earth changing and what are the consequences for life on Earth?

Research Questions

Prediction: How can knowledge of Earth's surface change be used to predict and mitigate natural hazards?

Forcing: What are the dynamics of the Earth's interior and how do these forces drive change at the Earth's surface?	**Variability:** How is the Earth's surface being transformed by naturally occurring tectonic and climatic processes?	**Response:** How is global sea level affected by natural variability and human induced change in the Earth system?

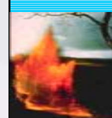
SESWG Challenge



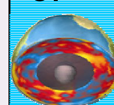
1. What is the nature of deformation at plate boundaries and what are the implications for earthquake hazards?

2. How do tectonics and climate interact to shape the Earth's surface and create natural hazards?

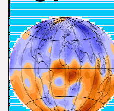
3. What are the interactions among ice masses, oceans, and the solid Earth and their implications for sea level change?



4. How do magmatic systems evolve and under what conditions do volcanoes erupt?

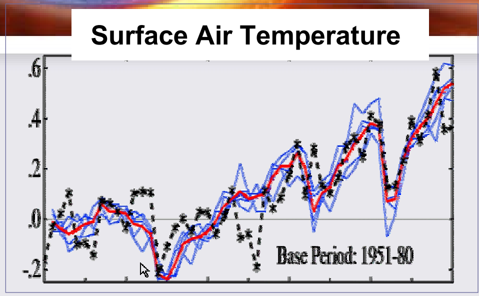


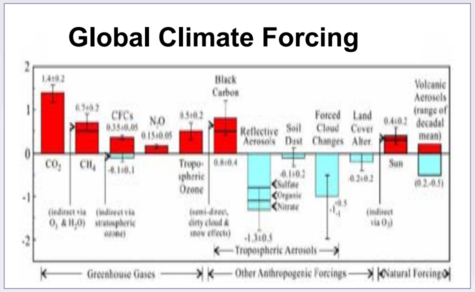
5. What are the dynamics of the mantle and crust and how does the Earth's surface respond?

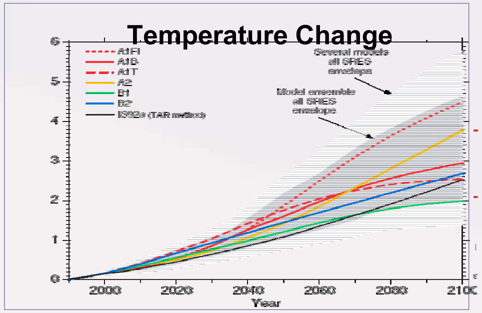


6. What are the dynamics of the Earth's magnetic field and its interactions with the Earth system?

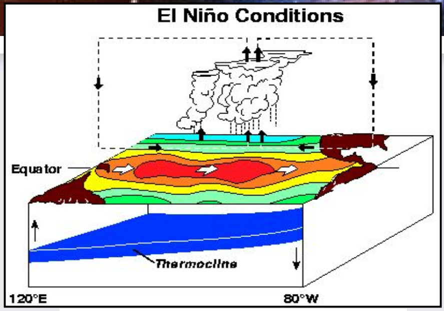
Climate Variability and Change

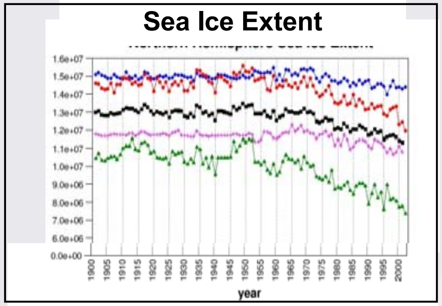


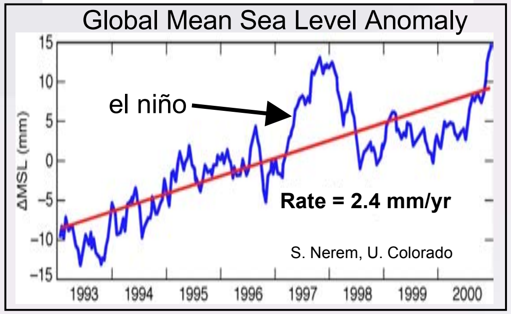




- How is global ocean circulation varying on interannual, decadal, and longer time scales?
- What changes are occurring in the mass of the Earth's ice cover?
- How can climate variations induce changes in the global ocean circulation?
- How is global sea level affected by natural variability and human-induced change in the Earth system?
- How can predictions of climate variability and change be improved?







Climate change is one of the major themes guiding Earth System Science today. NASA is at the forefront of quantifying forcings and feedbacks of recent and future climate change. Our comprehensive end-to-end program ranges from global high-resolution observations to data assimilation and model predictions.

National Weather Forecast Improvement Goals

TODAY:

- Reliable 3-day forecasts of non-extreme weather
- 13-hour winter storm forecast
- 3-day severe local storm forecast with low-moderate confidence
- 16-minute thunderstorm advanced warning
- Tornado lead time 12 min
- Hurricane landfall tracking:
  +/- 240 km at 2-3 days
- Inconsistent hurricane intensity forecasts
- Air quality day-by-day

GOALS for 2015:

- Reliable 5-day forecasts of non-extreme weather
- 24-hour winter storm forecast
- 5-day severe local storm forecast with moderate confidence
- 30-minute thunderstorm advanced warning
- Tornado lead time 20 min
- Hurricane landfall tracking:
  +/- 160 km at 2-3 days
- Dependable hurricane intensity, precip forecasts
- Air quality forecast at 2 days

SSSC Scientific Objectives

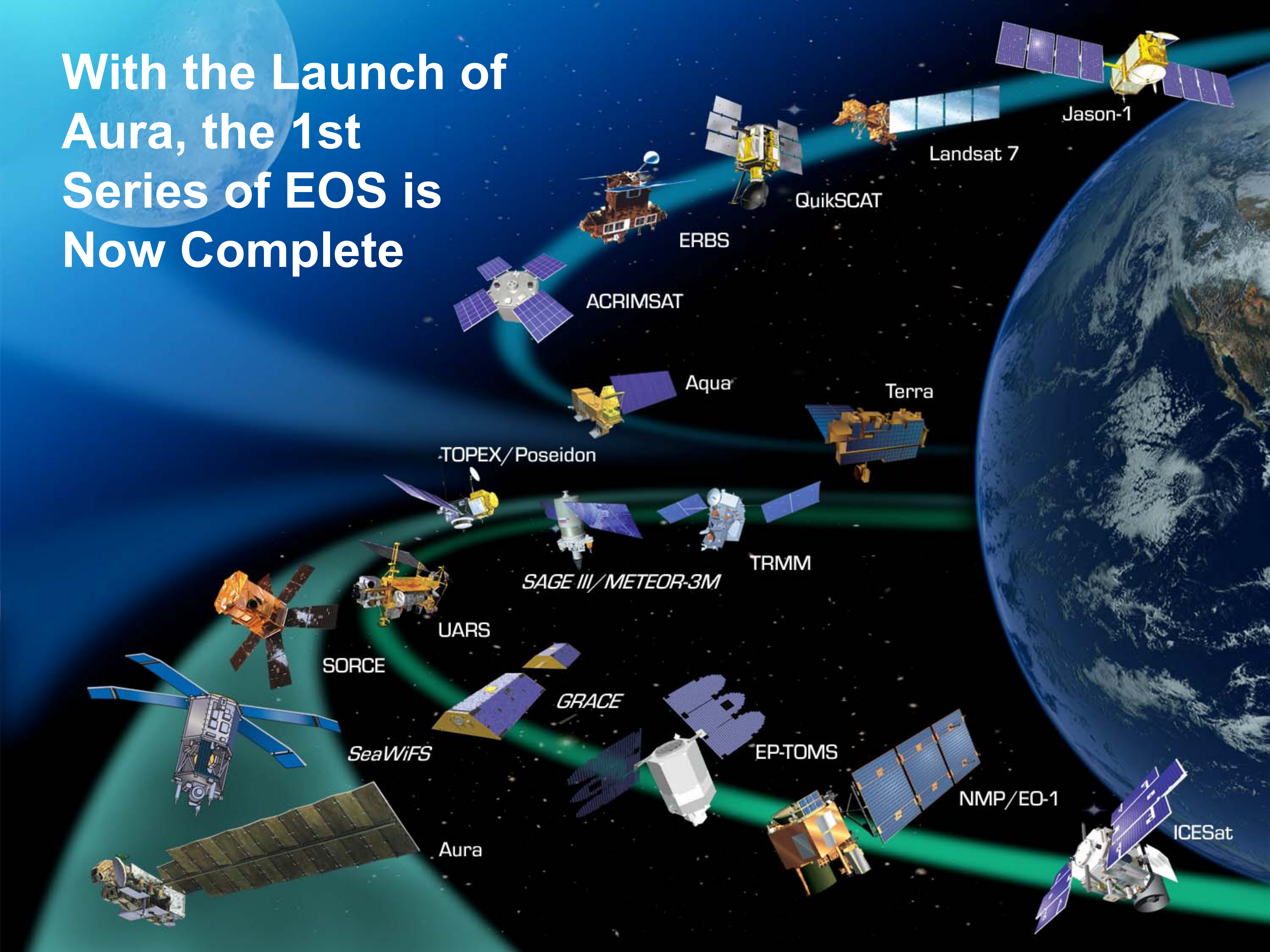
SEC Strategic Goal: *Understand how the Sun, heliosphere, and the planets are connected in a single system.*

- Explore the fundamental physical processes of plasma systems in the universe

- Understand the changing flow of energy & matter throughout the sun, heliosphere, and planetary environments

- Define the origins and societal impacts of variability in the Sun-Earth Connection

With the Launch of Aura, the 1st Series of EOS is Now Complete



Wind
Voyager 1 & 2
Jason-1
RHESSI
Geotail
Aqua
SOHO
TIMED
QuikSCAT
ERBS
TRACE
ACE
Cluster
ACRIMSAT
IMAGE
Landsat 7
NMP/EO-1
Ulysses
Polar
TOPEX/Poseidon
FAST
TRMM
SAGE III/METEOR-3M
SORCE
UARS
GRACE
EP-TOMS
SeaWiFS
Terra
ICESat
Aura

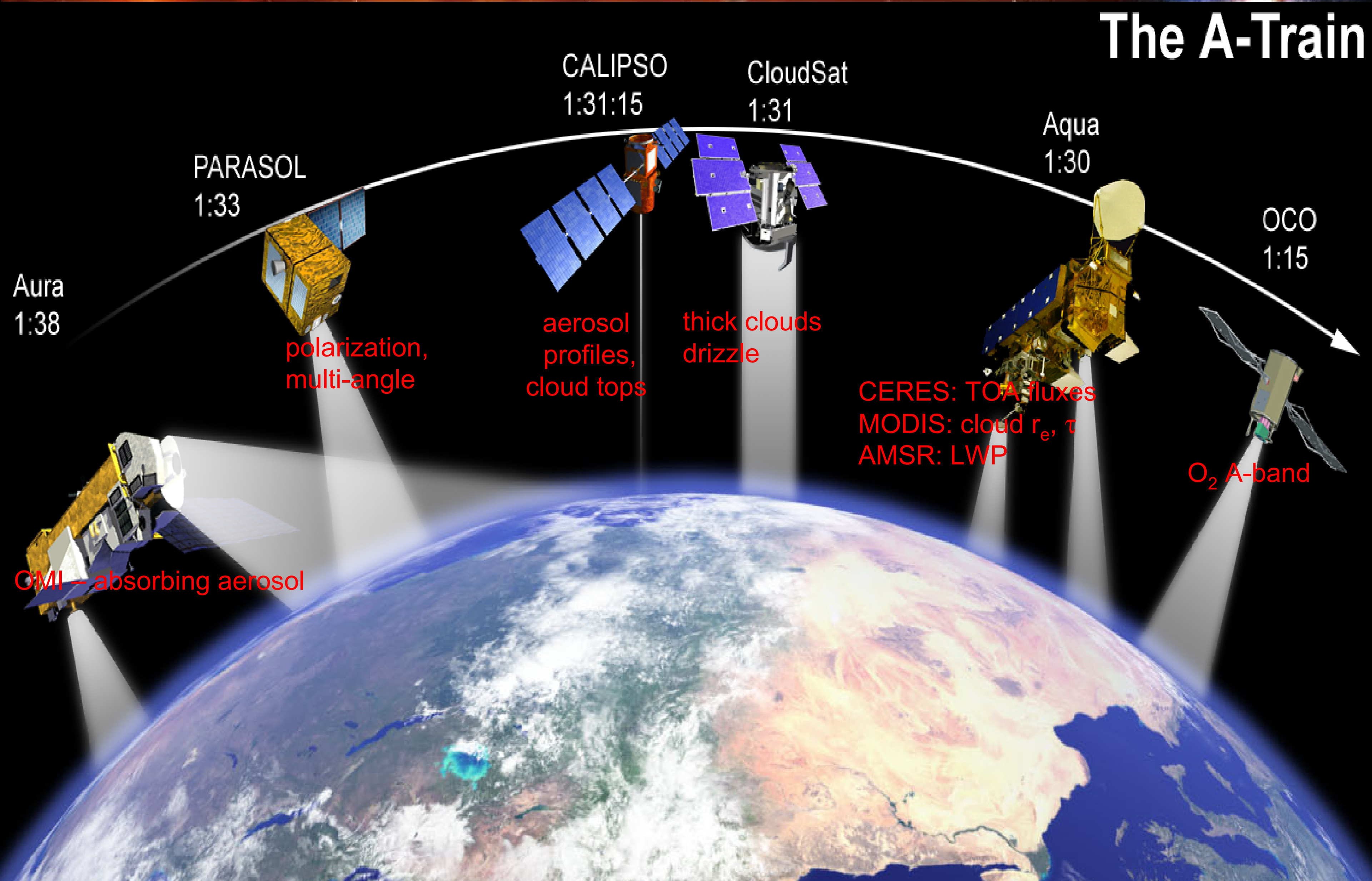
A Mission Dedicated to the Health of the Earth's Atmosphere

Aura

The Earth's Ozone Shield protects all life
The Earth's Air Quality is fundamental to public health and ecosystems
The Earth's Climate is affected by changes in atmospheric composition

Aura is designed to answer questions about changes in our life-sustaining atmosphere

- The observatory is in a nominal and stable operating condition.
- The Flight Support Team continues with the execution of the Aura activation and check-out plan.
- MLS, TES and OMI instruments are operating nominally and beginning to return data.
- HIRDLS has experienced an anomaly and is in safe mode while the cause is investigated.


The A-Train
CALIPSO
1:31:15
CloudSat
1:31
Aqua
1:30
PARASOL
1:33
OCO
1:15
Aura
1:38
aerosol
profiles,
cloud tops
thick clouds
drizzle
polarization,
multi-angle
CERES: TOA fluxes
MODIS: cloud r_e, τ
AMSR: LWP
O_2 A-band
OMI – absorbing aerosol

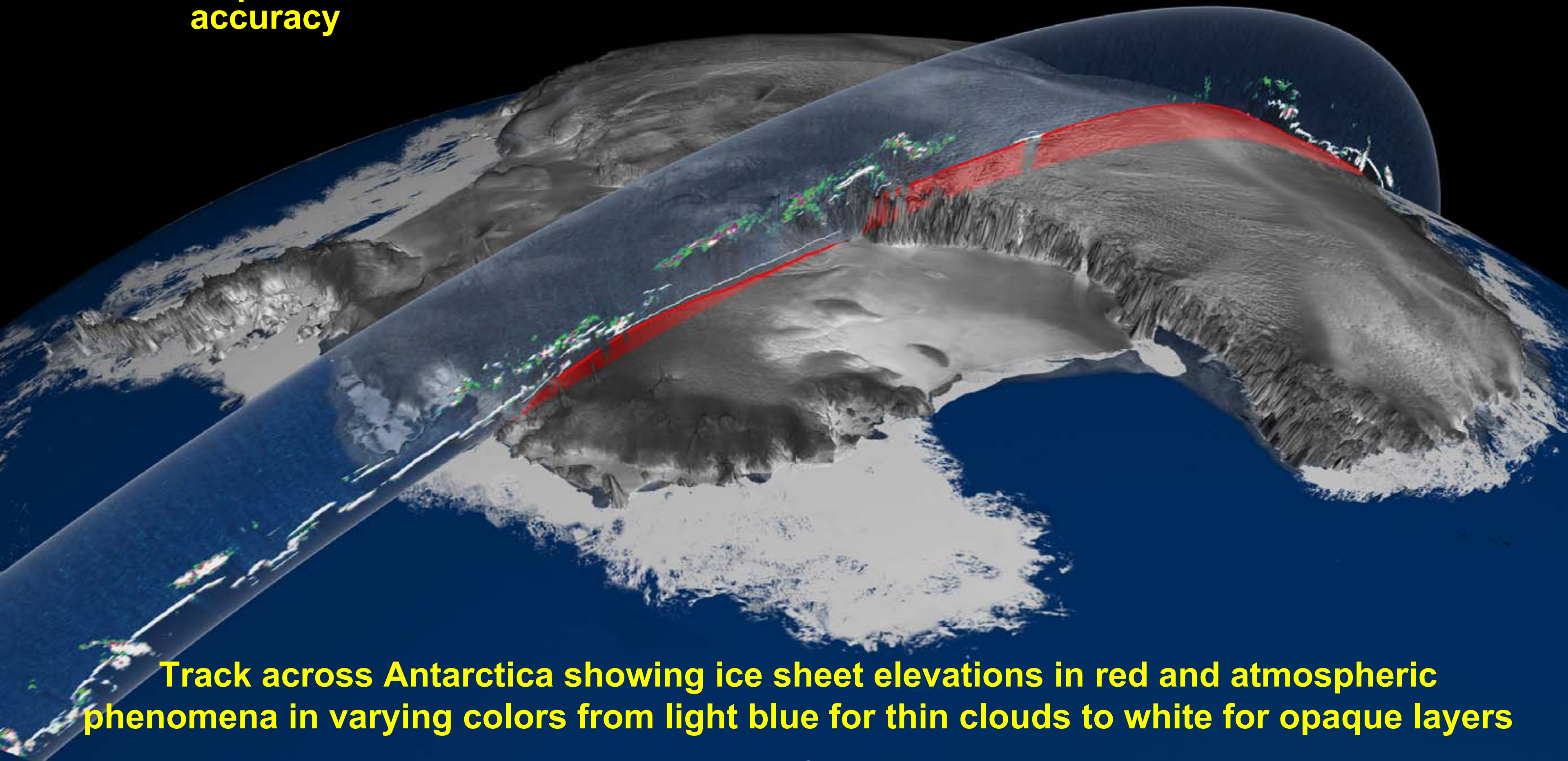
Ice Cloud and land Elevation Satellite (ICESat)

Precisely determines surface elevations

- 15 cm accuracy over ice
- Ground-breaking pointing capabilities
- Unprecedented orbit accuracy

ICESat Science Objectives

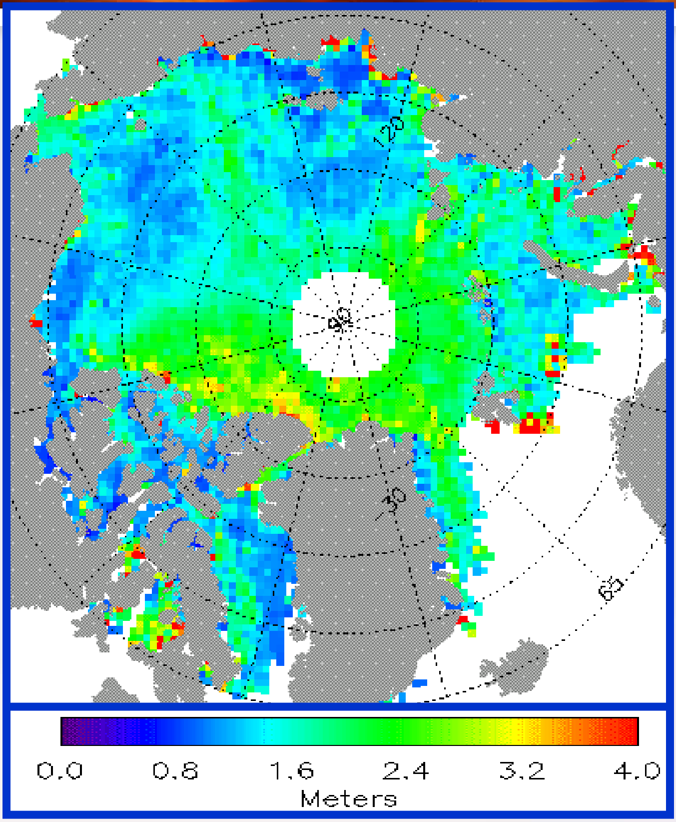
- Polar ice-sheet elevation changes and mass balance
- Atmosphere-cloud heights and aerosol distribution
- Land topography



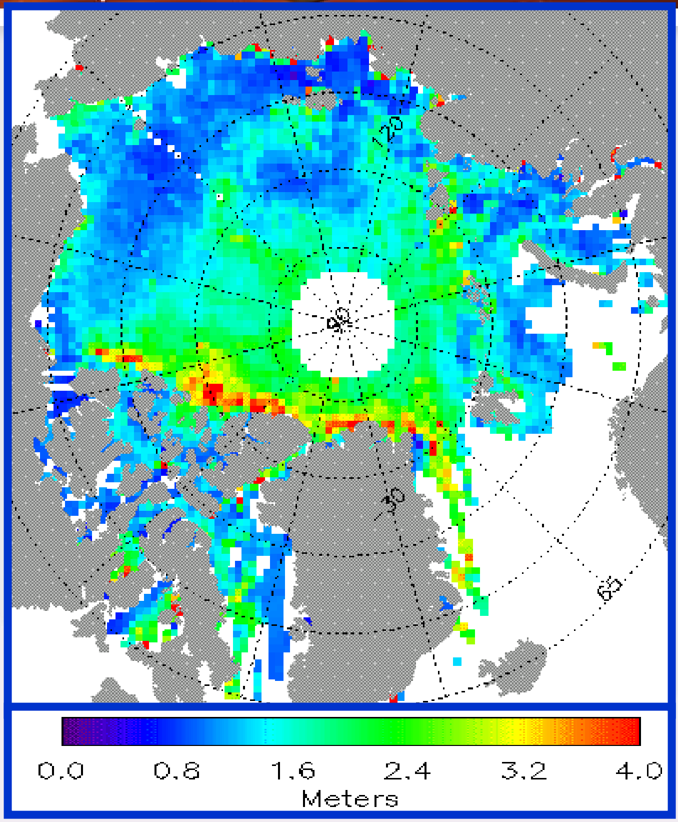
Track across Antarctica showing ice sheet elevations in red and atmospheric phenomena in varying colors from light blue for thin clouds to white for opaque layers

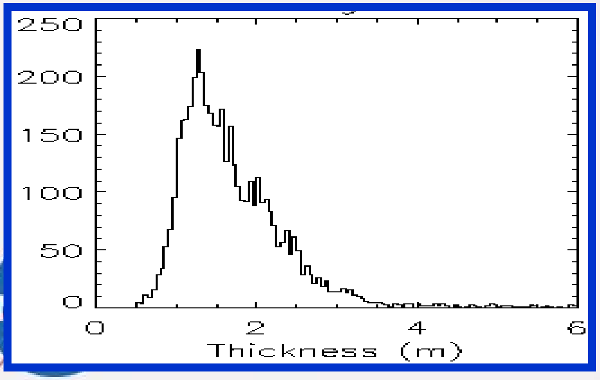
Inter-annual Change in Arctic Sea Ice Thicknesses

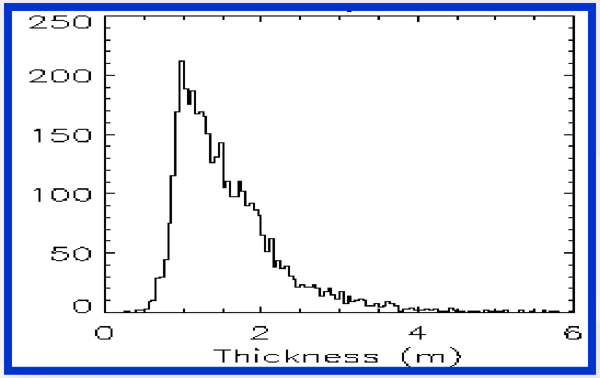
March 2003 ICESat laser 1



March 2004 ICESat laser 2b



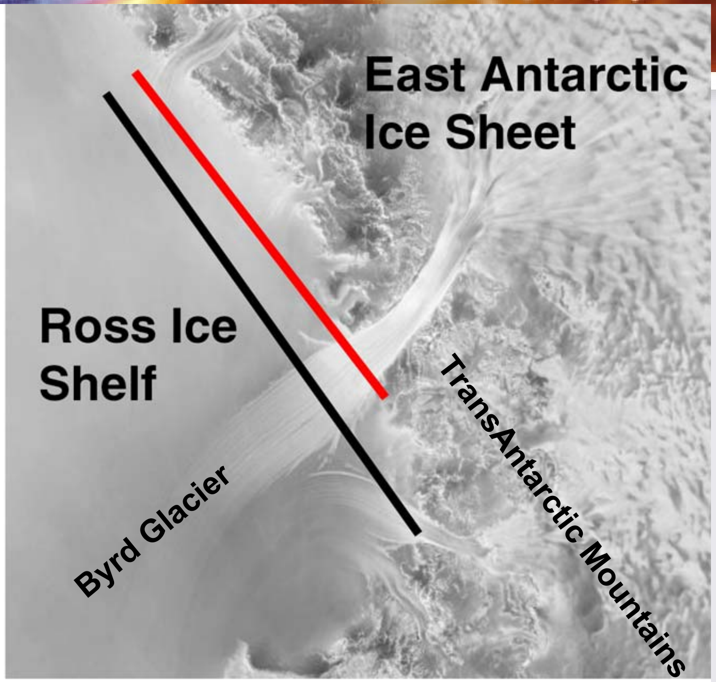


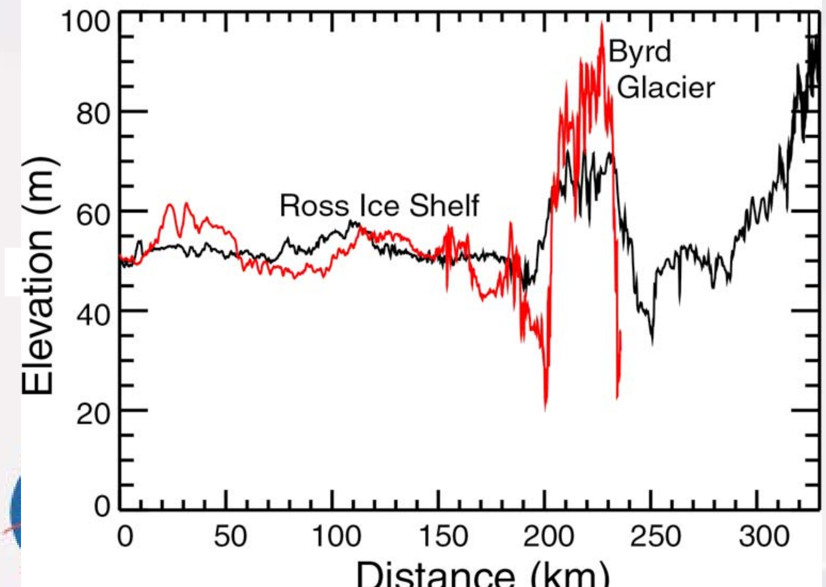


In winter 2004 the thicker ice is more confined toward the Canadian Arctic and Greenland, with larger area of thinner ice in seas north of Asia, compared to 2003.

Zwally et al, preliminary Results. NASA GSFC April, 2004.

Elevation Profiles for Studying Change





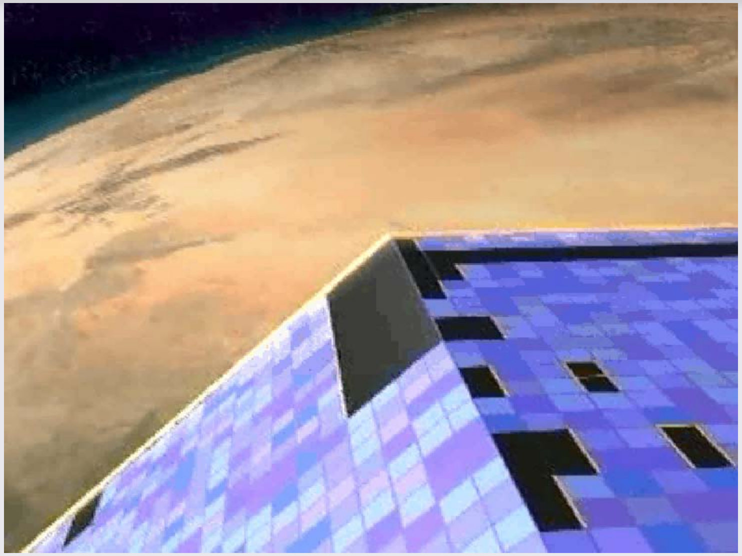
- Portions of two ICESat profiles show changes to the Byrd Glacier as it flows from East Antarctica, crosses through the TransAntarctic Mountains, and then discharges into the Ross Ice Shelf

- The red-line, more upstream, shows a thicker, narrower glacier

- The black line (further into the ice shelf) shows that ice flow has caused the Byrd to become wider and thinner

- Rough surfaces, such as crevasses, which have never before been observed from space with this degree of vertical before are also evident

GRACE Defined Goals



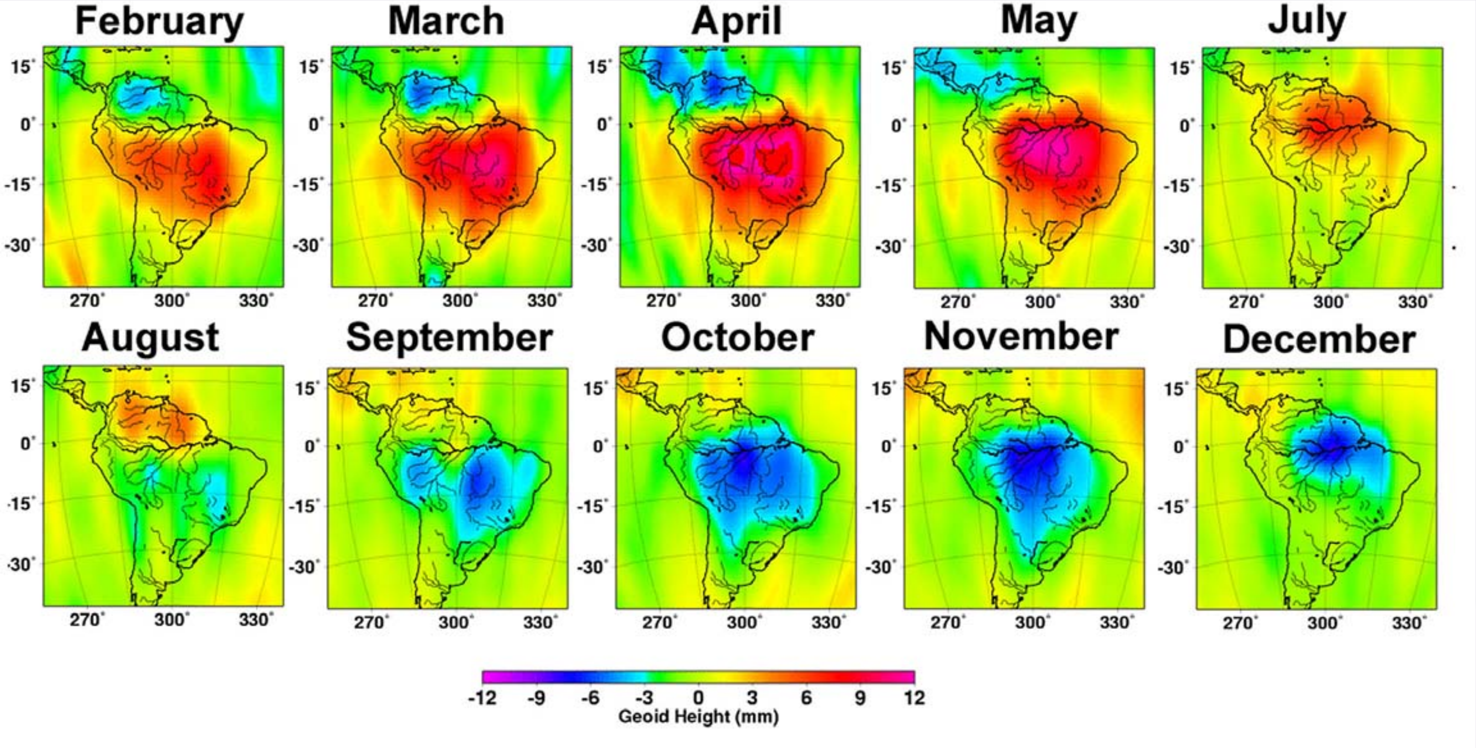
Minimum Mission: (Achieved)

1. Spherical Harmonic Model > degree and order 100 (~200 Km)
2. Cumulative error < 1 cm at degree and order 70 (~300 Km)

Baseline Mission:

1. Mean component: Degree and order 160 (~125 Km) (Achieved)
2. Time variable component: Degree and order 100 (~200 Km) at approx. 30 day intervals (11 months of data released-Jan 27,04)
3. 200 GPS atmospheric soundings/day subject to data system limitations. (TBD-instrument ready for turn on)
4. Goal of 0.4 mm geoid accuracy at 300 km resolution (TBD)

GRACE is Resolving Monthly Basin-Scale Variability



In 2003, mass variations are observed in Amazon basin with ~400 km resolution

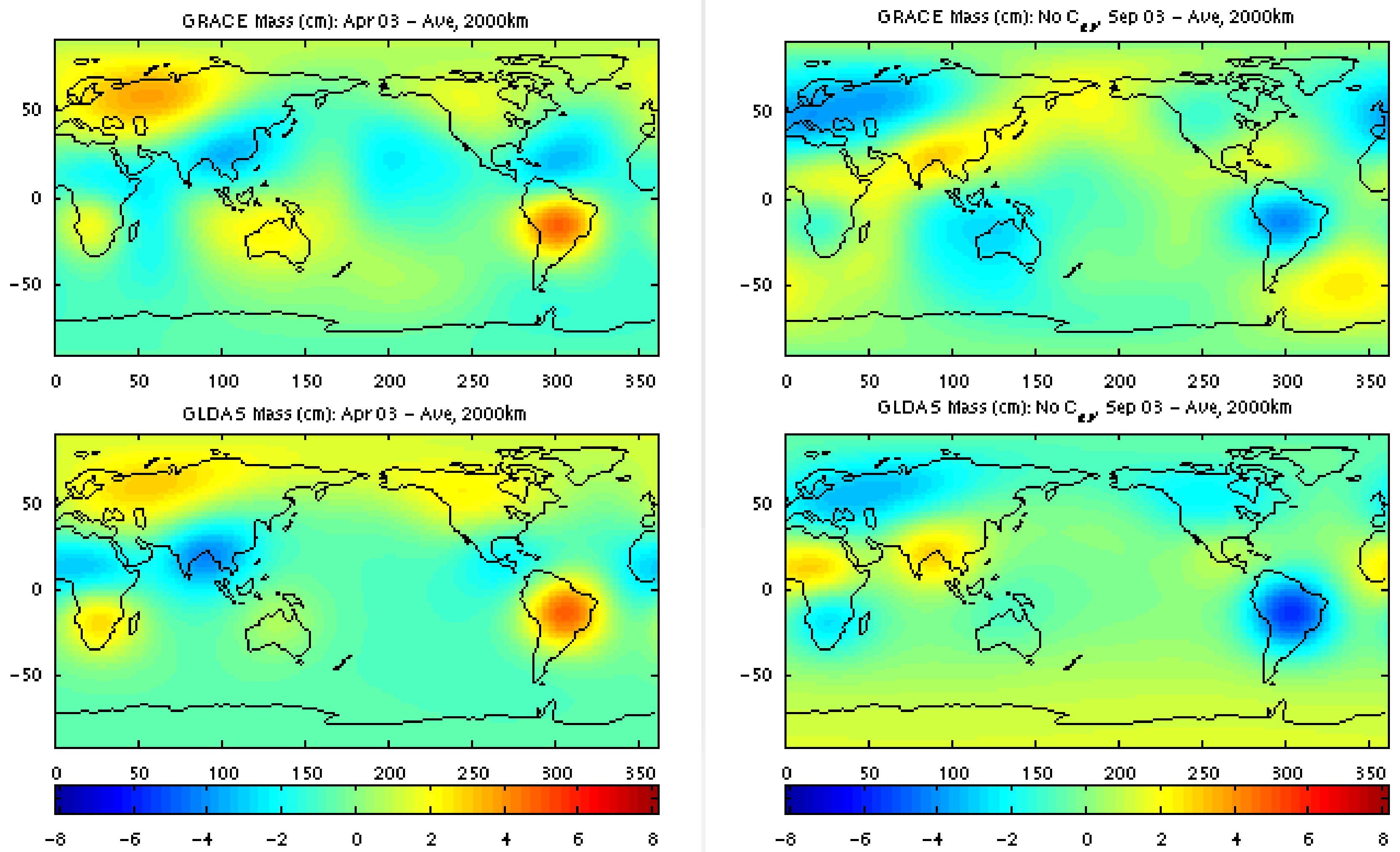
A clear separation is observed between the large Amazon watershed and the smaller watersheds to the north (e.g., the Orinoco watershed), indicating basin-scale resolution of the variability.

NASA JPL CSR GFZ POTSDAM DLR

Comparison of GRACE-Derived Terrestrial Water Storage with Modeled Soil Moisture + Snow

GRACE

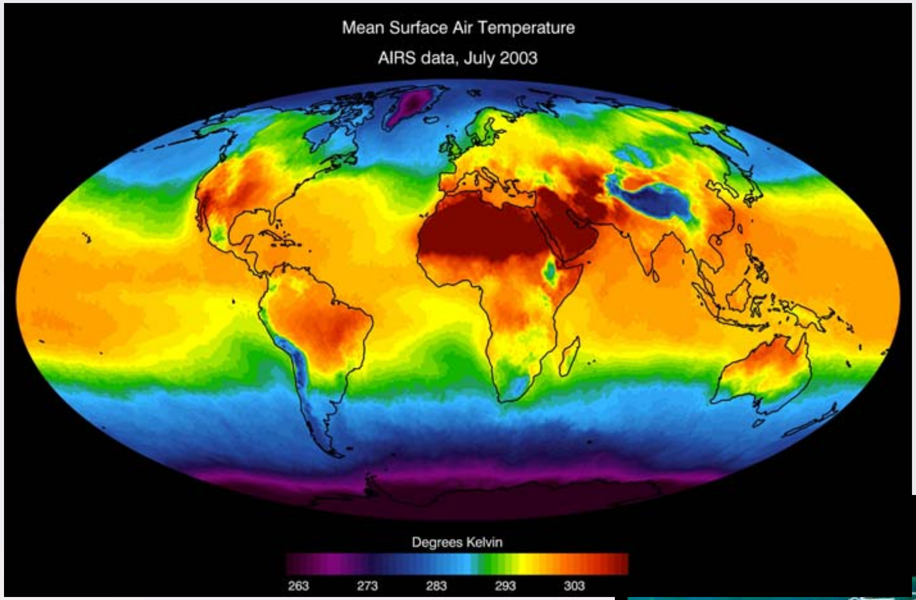
GLDAS

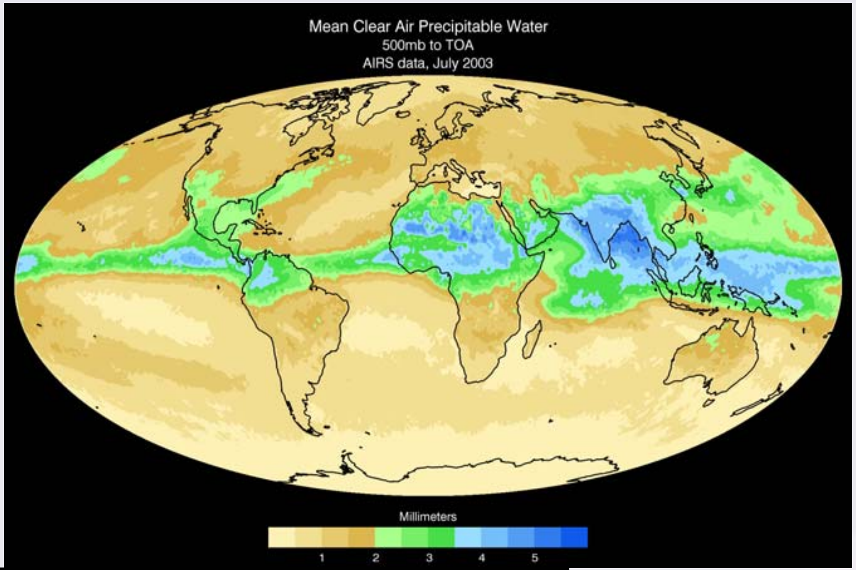


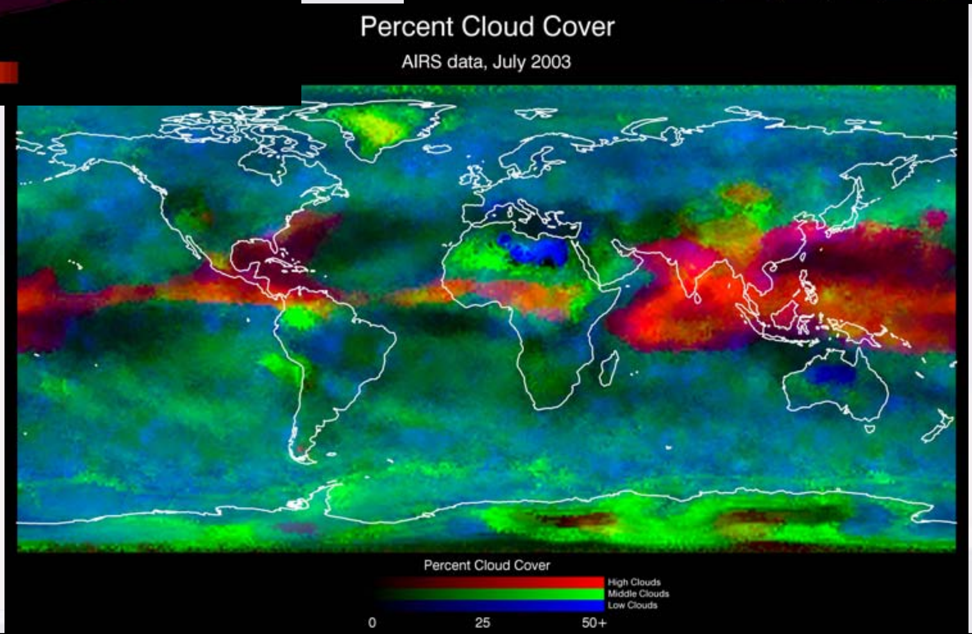
April 2003 **September 2003**

From M. Rodell, NASA/GSFC

Improving Climate Observations w/ Aqua



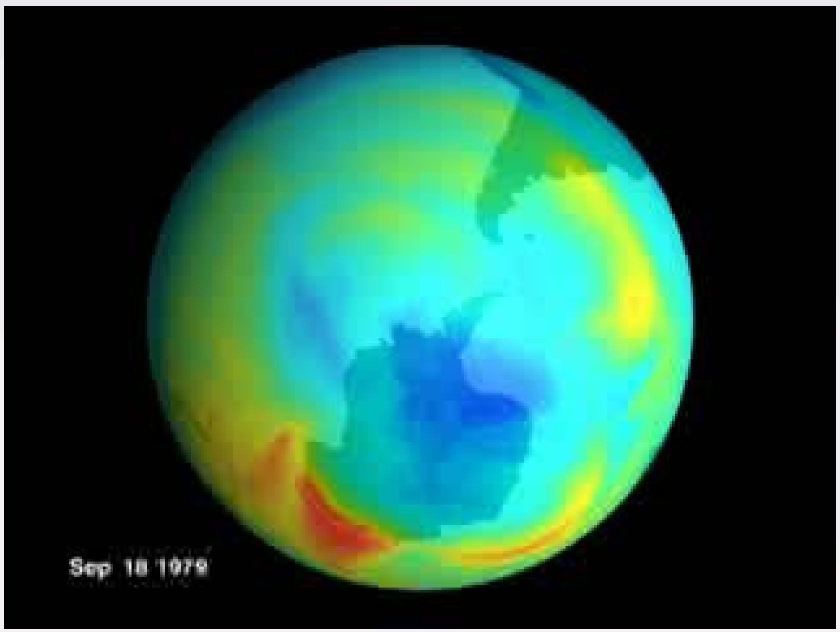


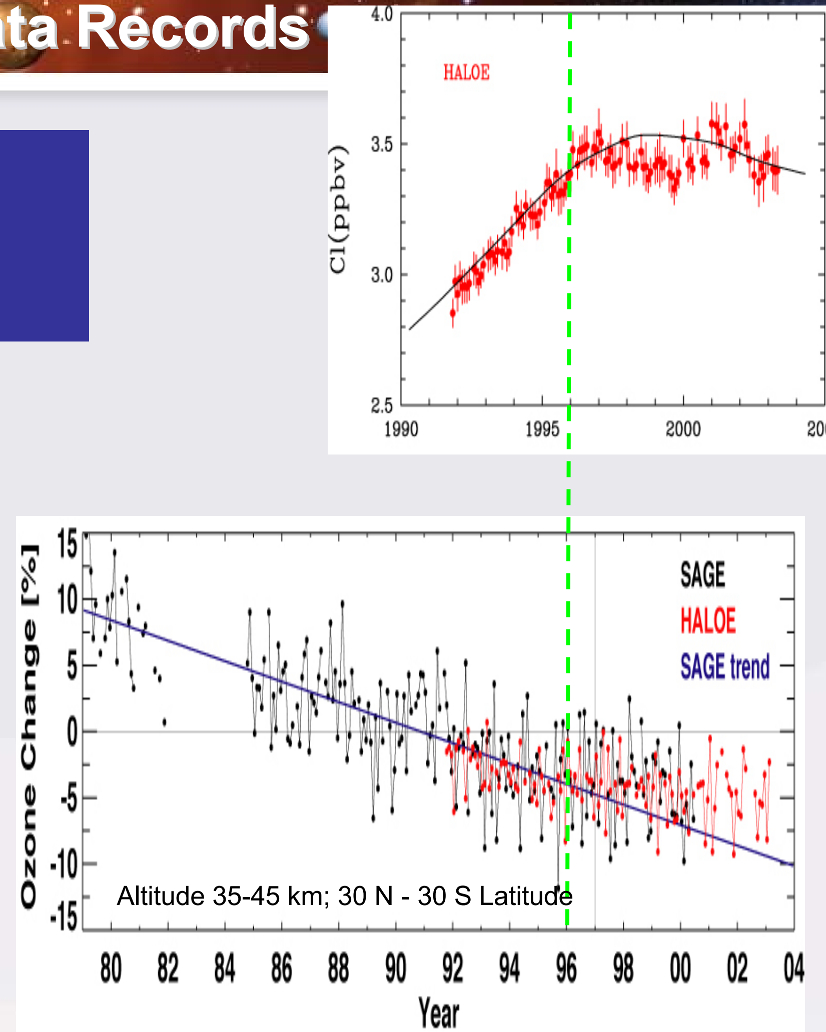


Mean temperature, percent cloud cover, and precipitable water for July 2003 from the AIRS instrument on the Aqua satellite

Slowdown in Ozone Loss Rate Observed in Climate Data Records

Flattening of ozone trend in 1996-2003 consistent with observed leveling off in total inorganic chlorine



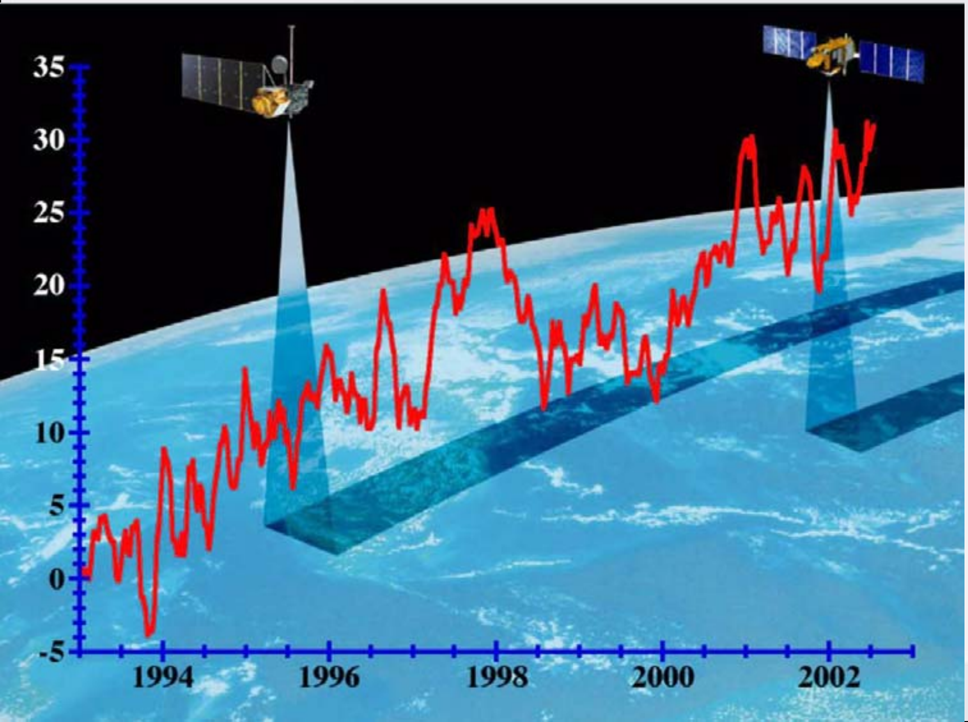


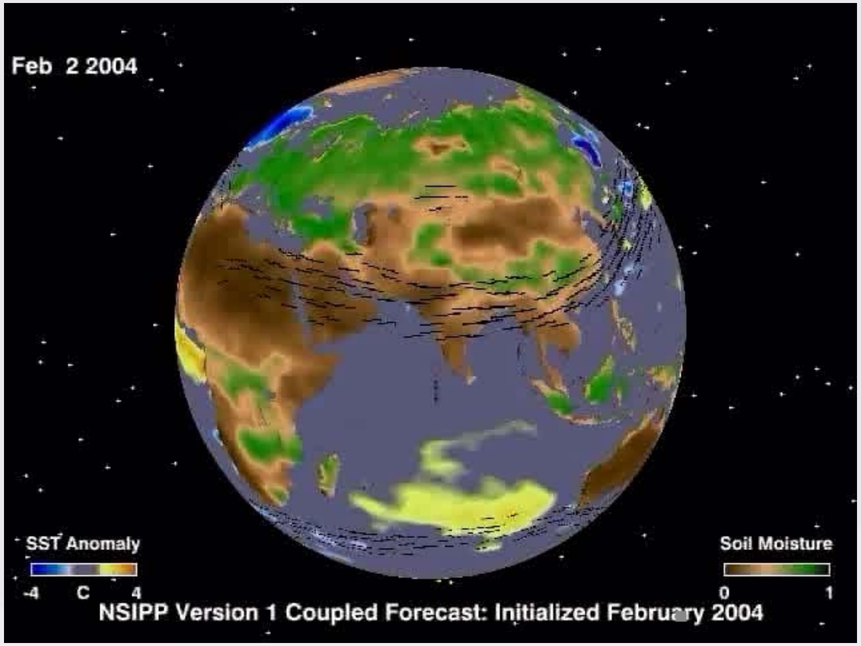
Top Panel: Russell and Anderson (Hampton U.)

Bottopm Panel: Newchurch, et al., "Evidence for slowdown in stratospheric ozone loss: First stage of ozone recovery," JGR 180 (D16), 4507.

Ocean Circulation & Climate Modeling

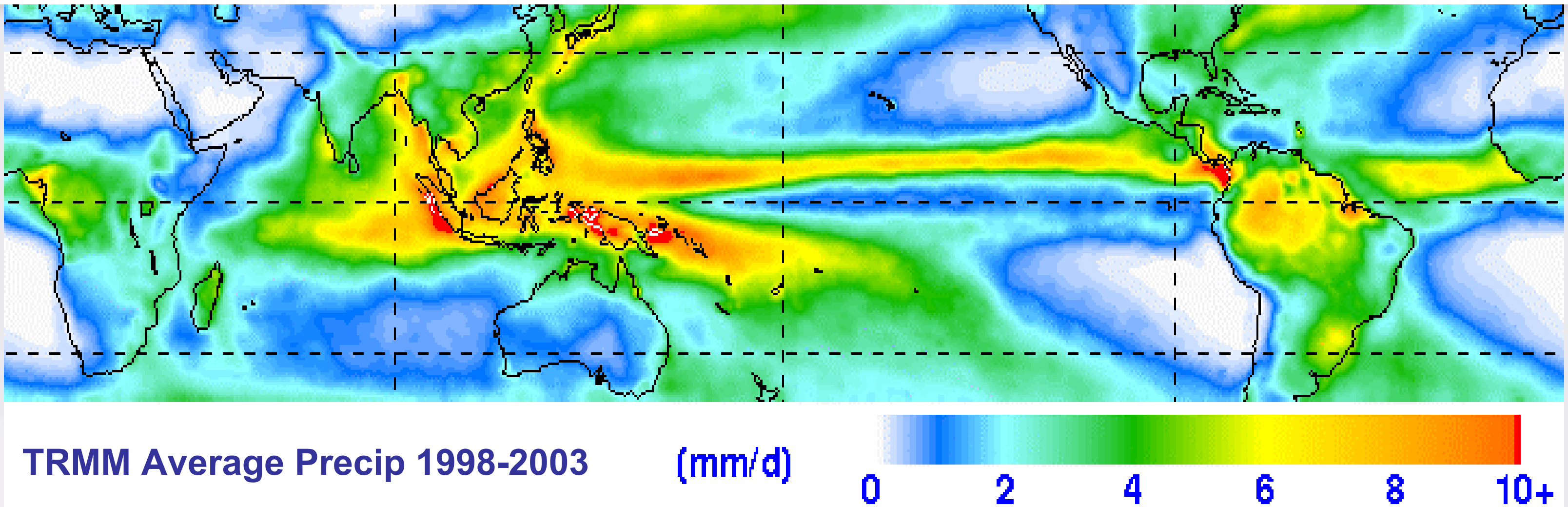
US/France Topex/Poseidon and Jason satellites have produced a 12 year record of ocean circulation and sea level change

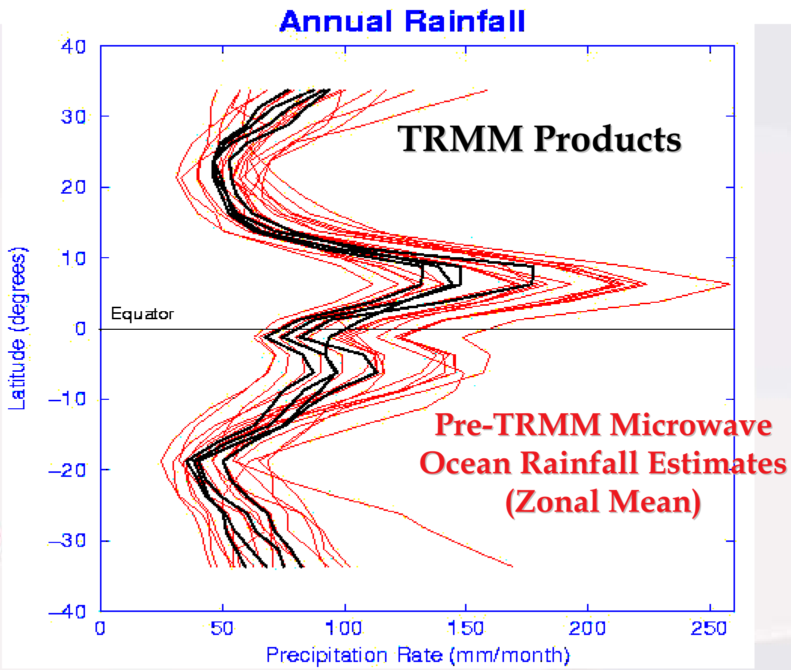




Climate models can now simulate land processes as a function of atmospheric and ocean temperatures

Tropical Rainfall Measuring Mission



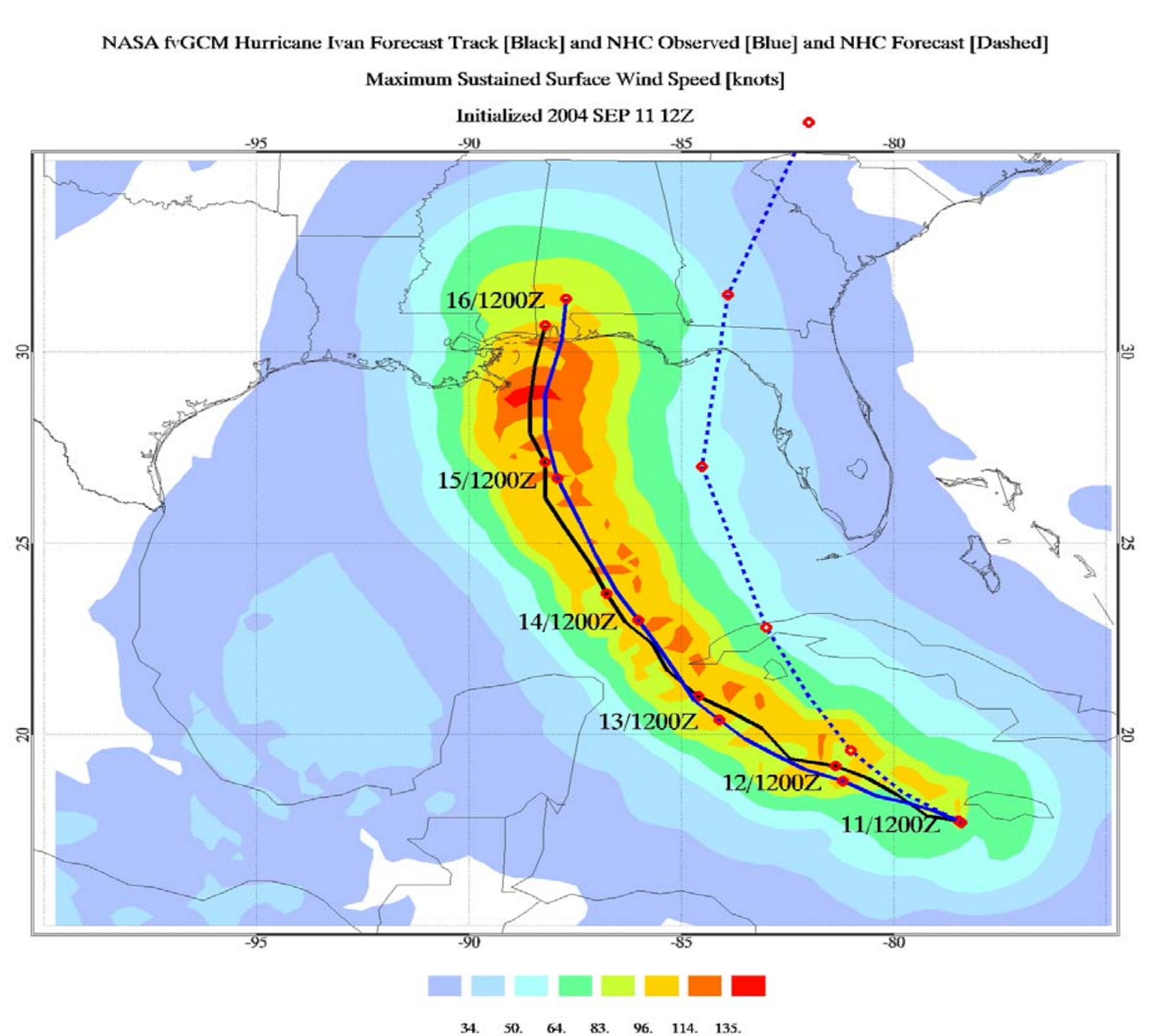


Improved Ocean Rainfall Estimation due to algorithm improvement from pre-TRMM (e.g. SSM/I) era

Uncertainties in Tropical Rainfall Estimates Reduced from ~50% to ~25% using TRMM

Hurricane Ivan
fvGCM Track and Intensity Forecast

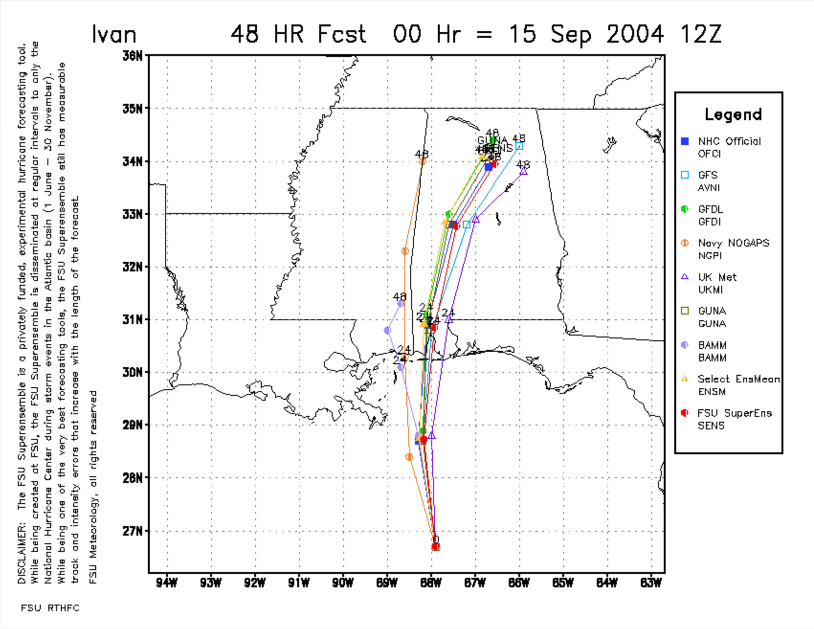
- NASA fvGCM 5-day forecast shows vast improvement in accuracy of track, landfall, and intensity over operational prediction in this case
- Uses data from operational satellites, SSM-I, TRMM and QuickSCAT



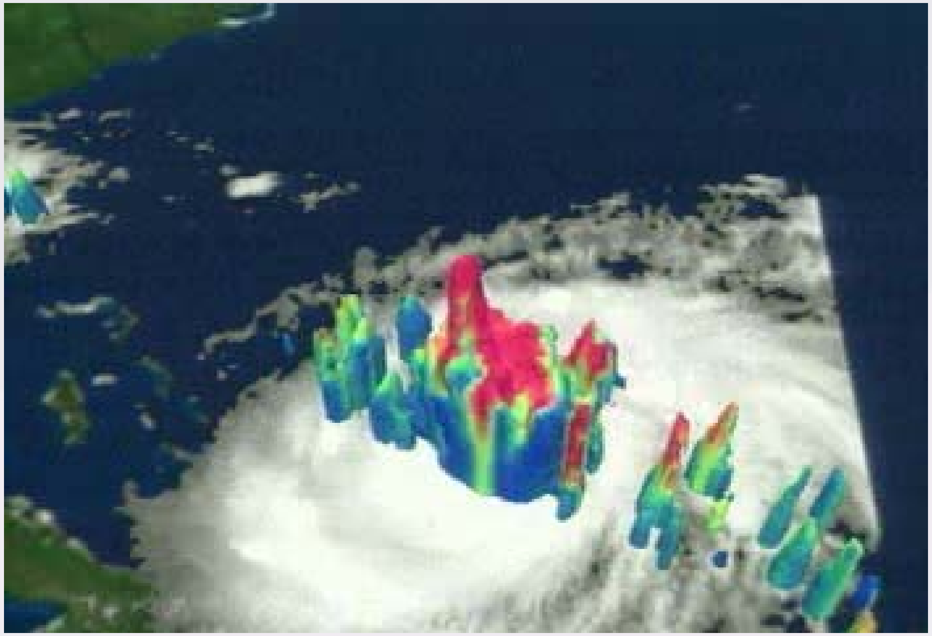
Modeling Hurricane Landfall

Assimilation of TRMM rainfall location, intensity and vertical structure into hurricane forecast models leads to improvements in forecasts of future position

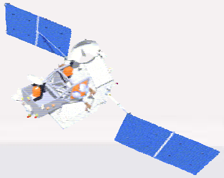
Hurricane Ivan Forecast, September 2005



Hurricane Visualization with TRMM data

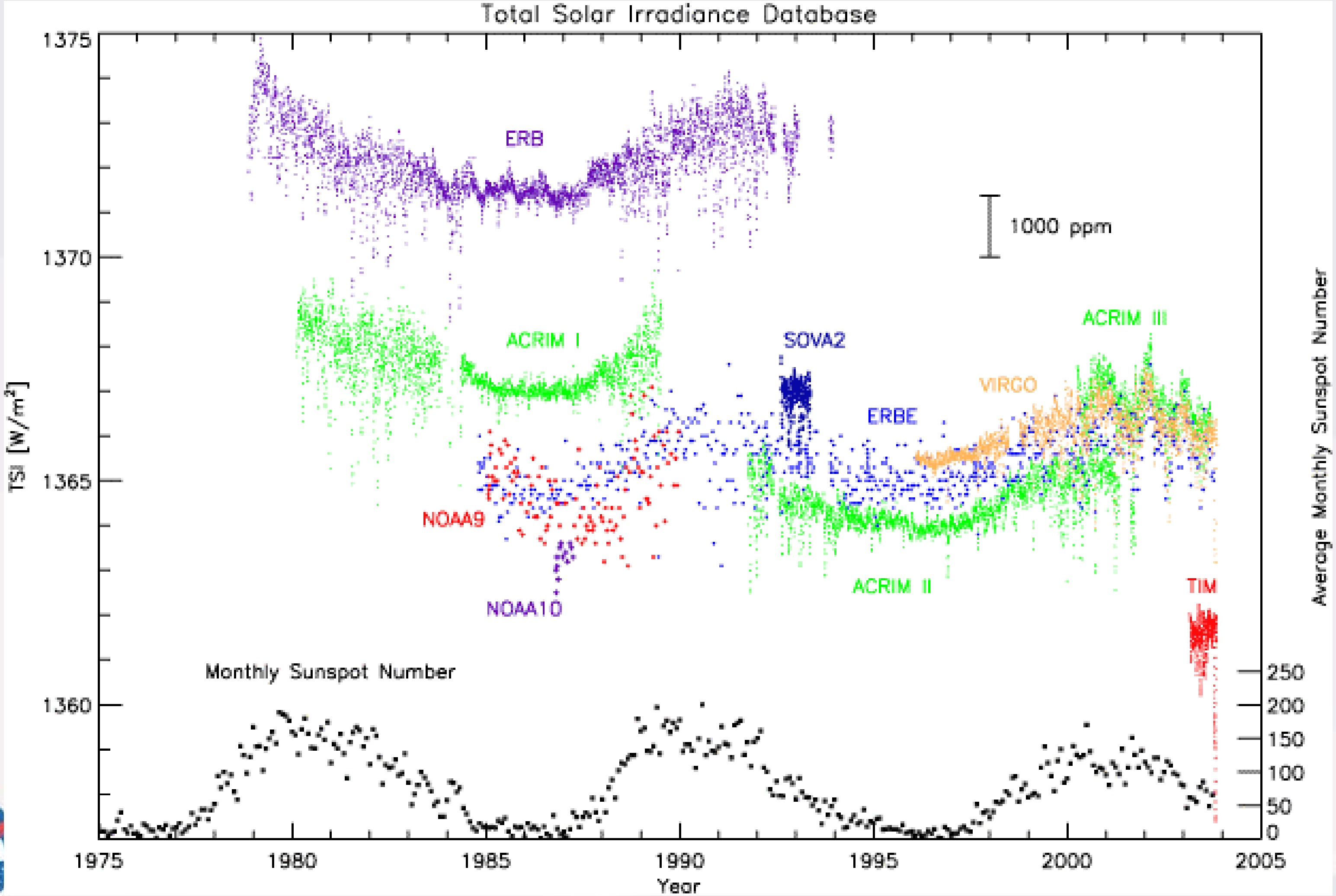


Reduced track errors can save money ($600K - $1M per mile of coast evacuated) and save lives by more precise prediction of eye location at landfall

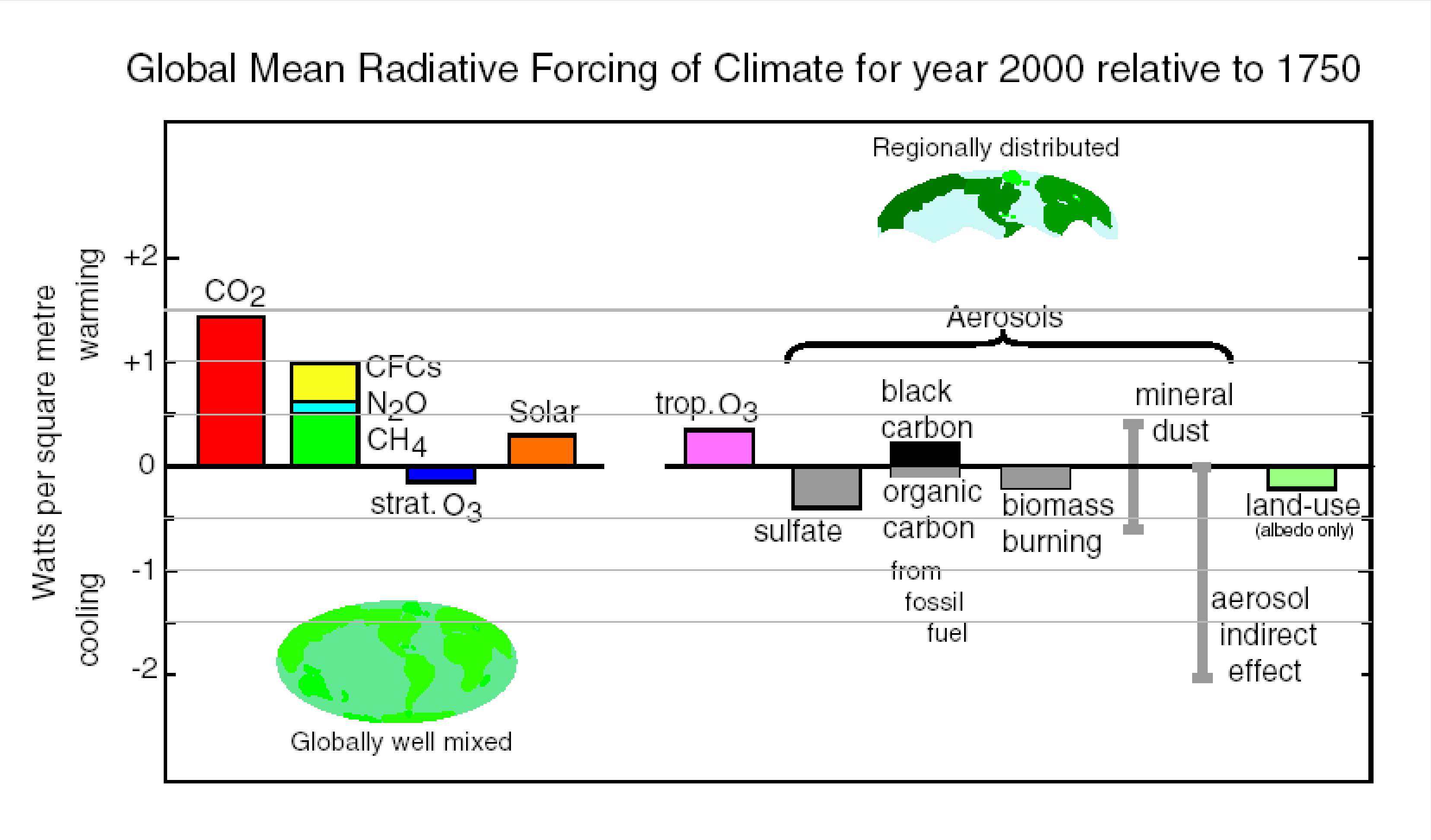


We Have A Three Decade Data Record

NASA Total Solar Irradiance Observations

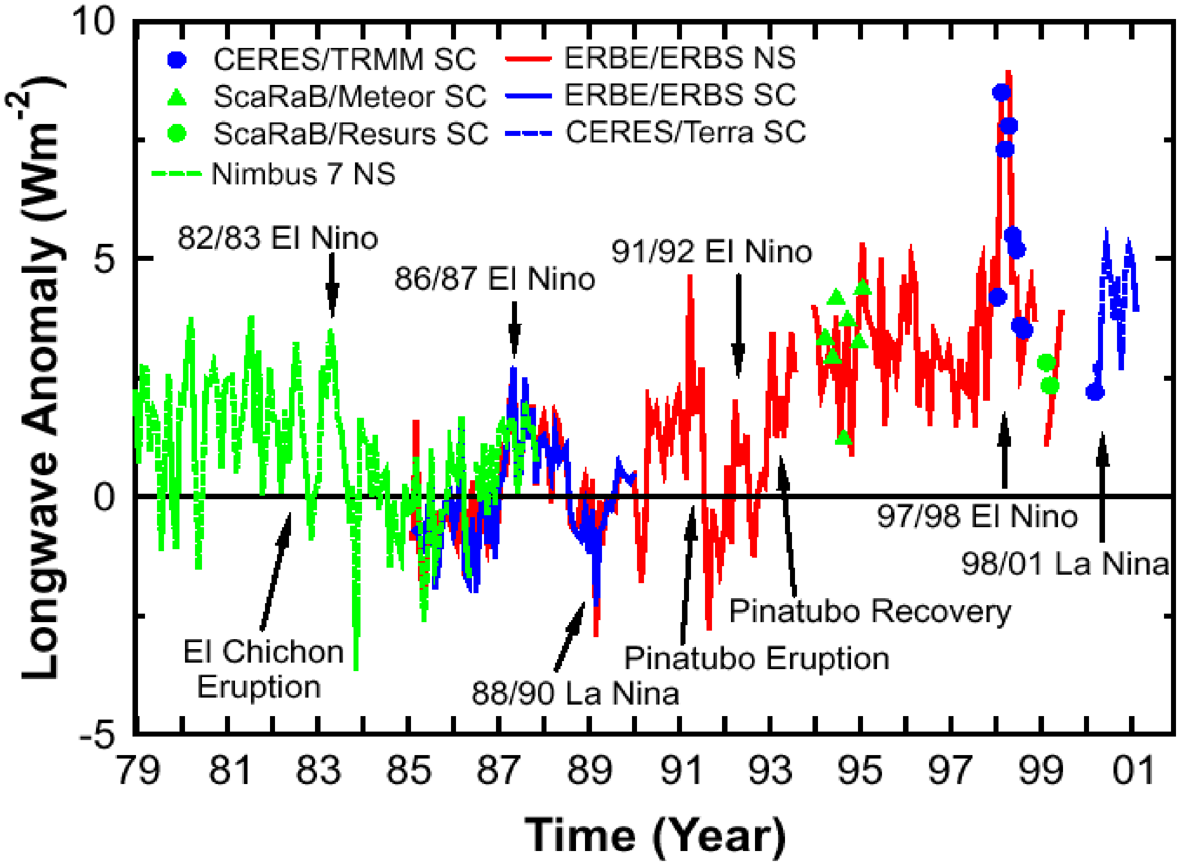


...And Climate Forcing is About Changing How the Climate System Responds



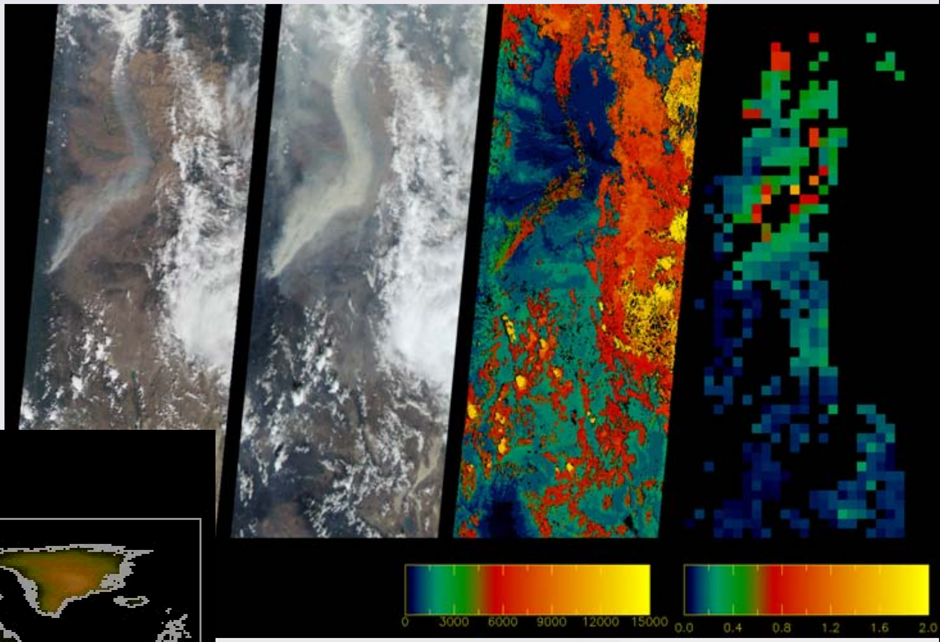
And Can Begin to Distinguish Solar From Terrestrial Influences

An overlapping Earth radiation climate record: 22 years from Nimbus 7 to Terra.



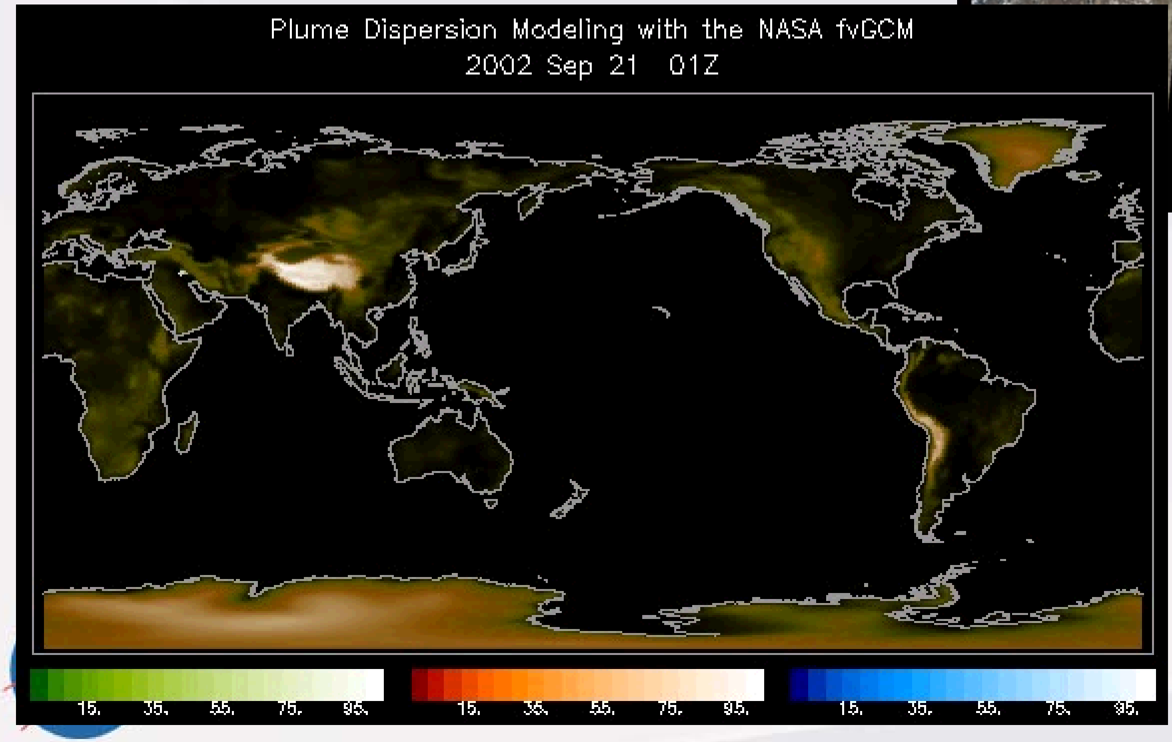
Key Climate Issue: Atmospheric Aerosols

Nadir 70°



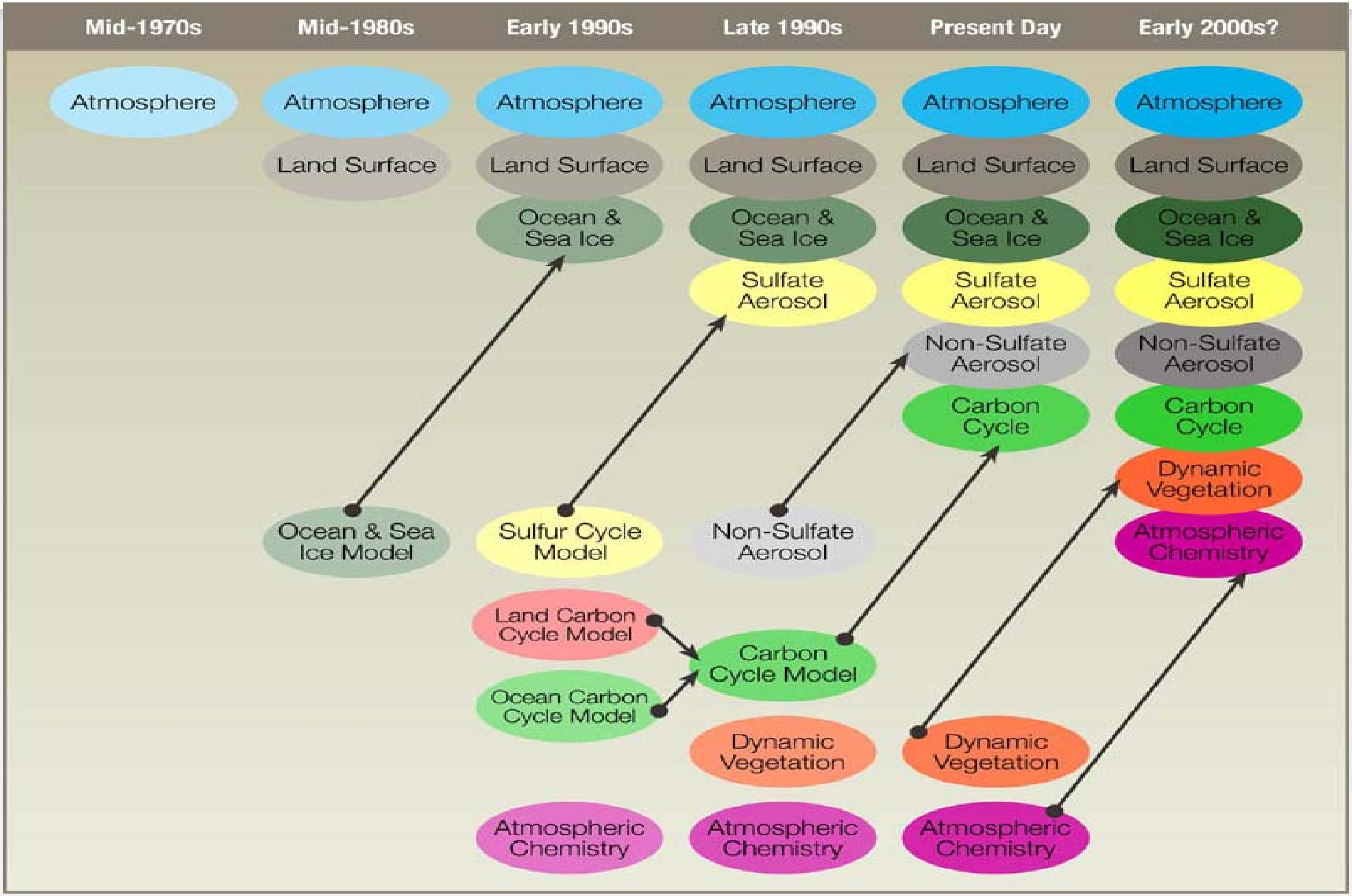
Stereo height **Aerosol OT**

Simulated plume dispersion demonstrating the ability to model with knowledge of the Earth atmosphere from satellites



B&B Complex Fire, Oregon
4 September 2003
from Terra-MISR

The Path Forward



Modeling & Computing Research

- Climate forcing, multi-decade, centennial assessment
- Ocean and Land Assimilation, Ocean-land-atmospheric interactions 6 –24 months
- Atmosphere, land-surface assimilation, assimilated data for mission support, observation impact, link between weather and climate
- PI-driven model development selected projects through numerous programs
- Engineering Component
  - Software engineering/Data assimilation methodologies/Computational technologies

Data Assimilation Office

Goddard Institute for Space Studies

NASA Seasonal Interannual Prediction Project

NASA/NOAA Joint Center for Satellite Data Assimilation

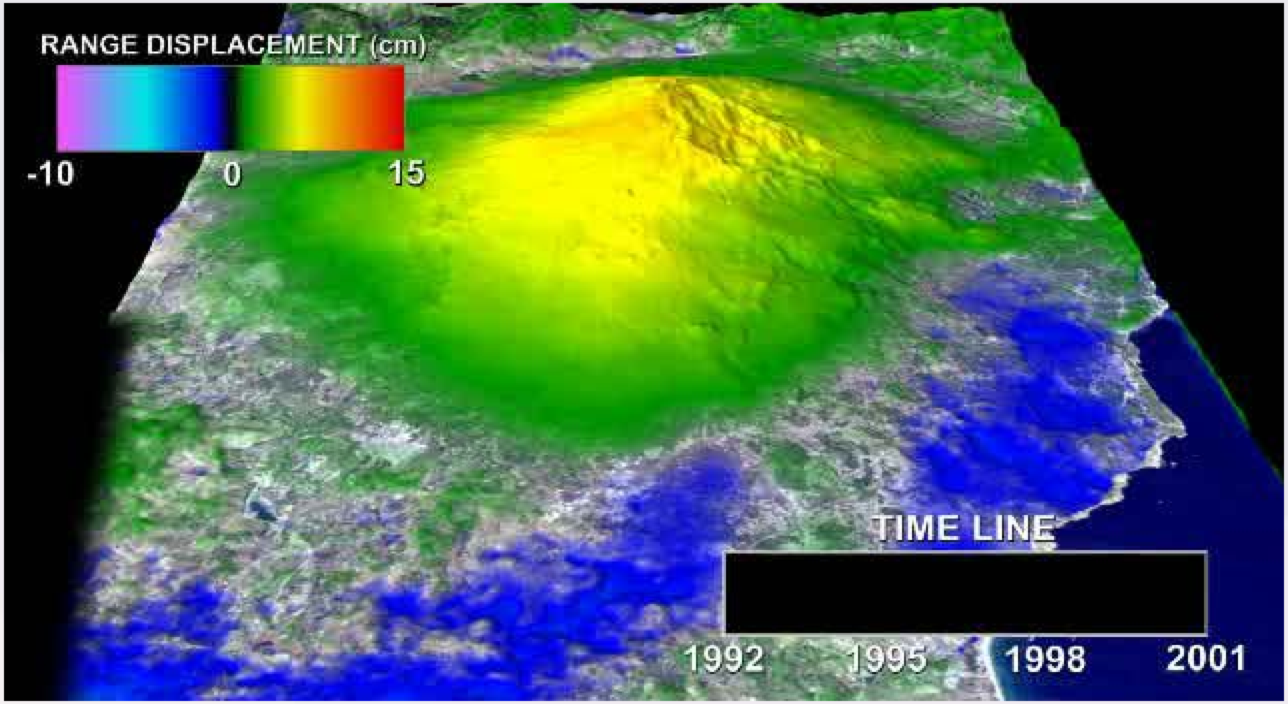
Computational Technologies

Earth Science Modeling Framework

The NASA Short-term Prediction Research & Transition Center

Modeling the Earth's Surface and Interior

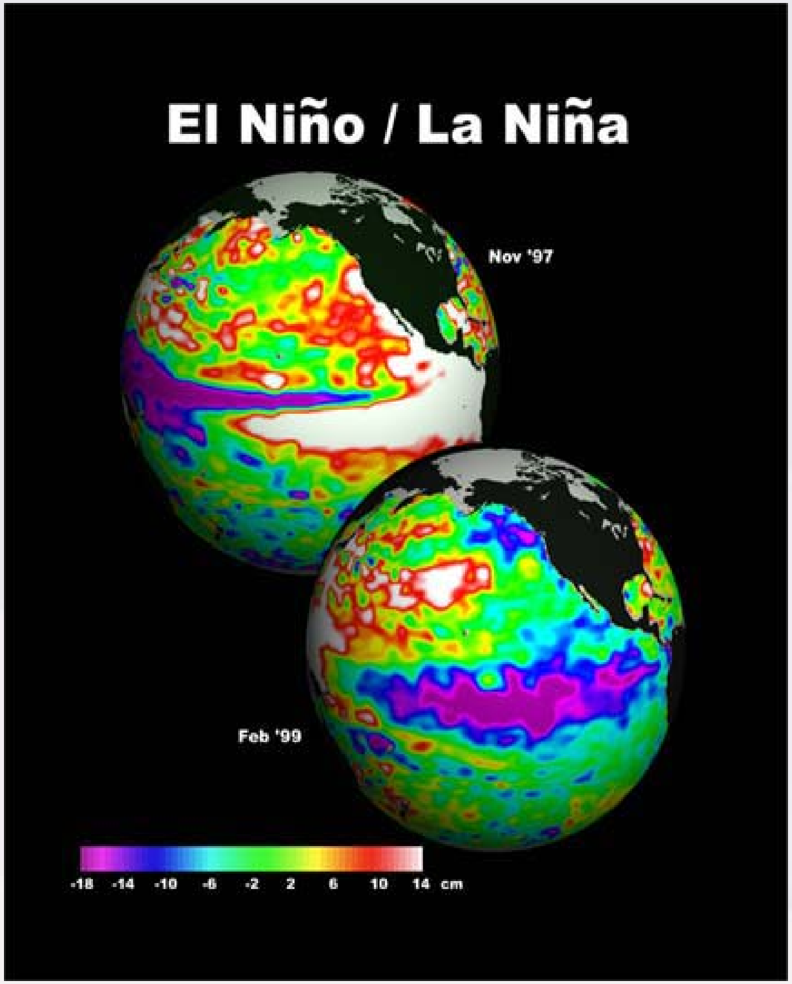
Volcano Eruption Prediction



Mount Etna

Taking the Pulse of Our Home Planet:
From Process to Prediction (1)

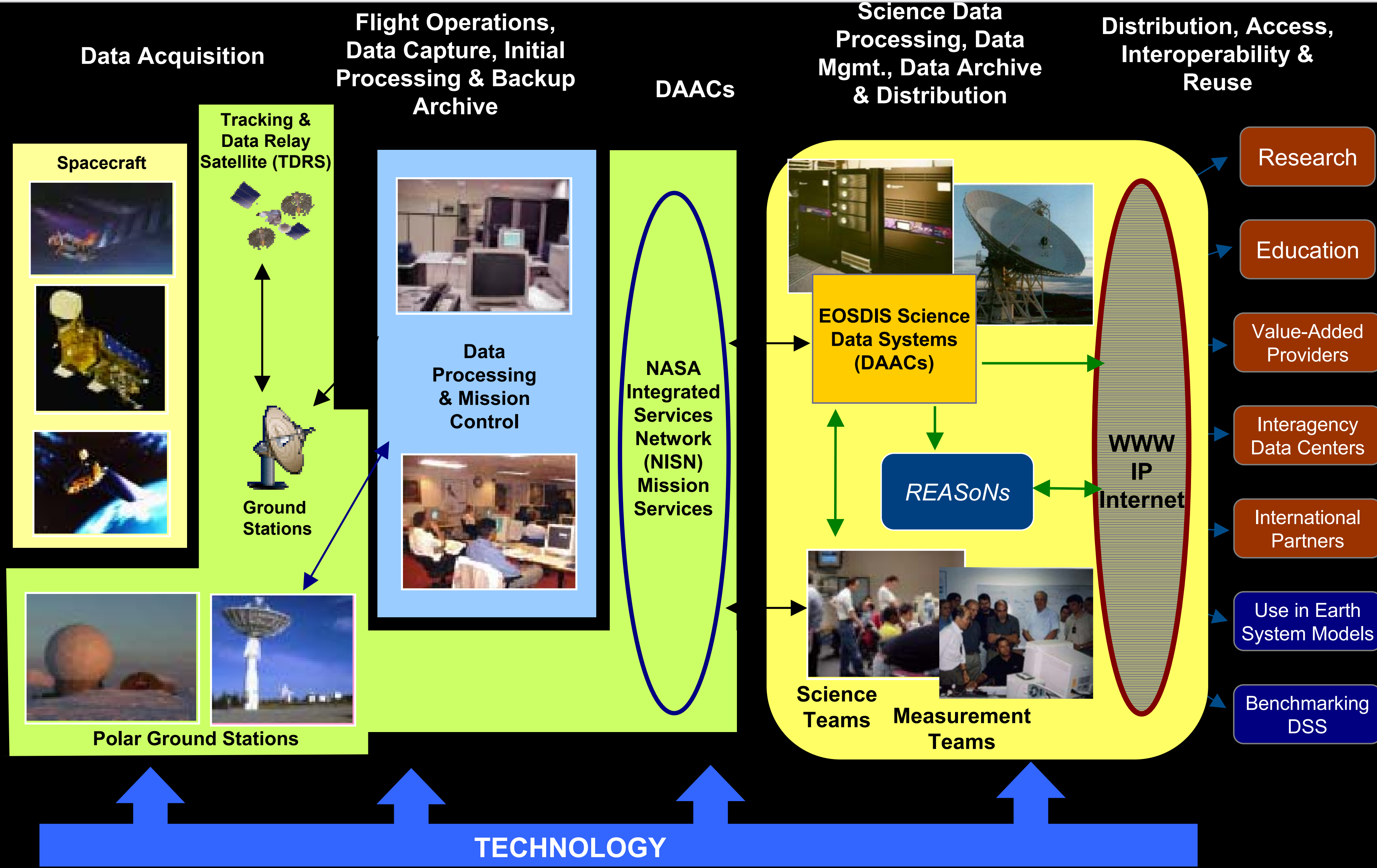
- Measuring and monitoring continental drift and plate tectonics, and understanding their impact on natural hazards, earthquakes and volcanoes
- Capturing and documenting dynamics of Earth's Ozone layer and understanding the effects of its depletion on exposure to UV radiation at the Earth's surface
- Capturing and documenting global ocean circulation and its role in Earth's weather and climate
- Documenting land cover change at global and regional scales in response to natural and human influences
- Capturing the seasonal dynamics of land vegetation and ocean phytoplankton, and their capacity to cycle carbon through the Earth system and in food and fiber production
- Mapping the 3-D structure of storms and hurricanes and their impacts on human safety, property, and infrastructure



Taking the Pulse of Our Home Planet:
From Process to Prediction (2)

- Mapping Greenland and Antarctic ice sheets in 3-D with unprecedented accuracy to understand their role in Earth's weather, climate and sea level change
- Measuring the Earth's Radiation budget and its variations with unprecedented accuracy to assess its impacts on Earth's climate and weather
- Measuring Earth's gravity field and its variations over time with unprecedented accuracy to assess its role in ocean circulation and Earth's climate
- Measuring the distribution of aerosols and clouds and assessing their roles in Earth's climate and energy budget
- Mapping the Earth's surface in 3D with unprecedented accuracy and resolution and using this knowledge to improve understanding of floods, landslides, earthquakes & volcanoes

From Data Acquisition to Data Access



Earth System Data Resides in Distributed Active Archive Centers (DAAC)

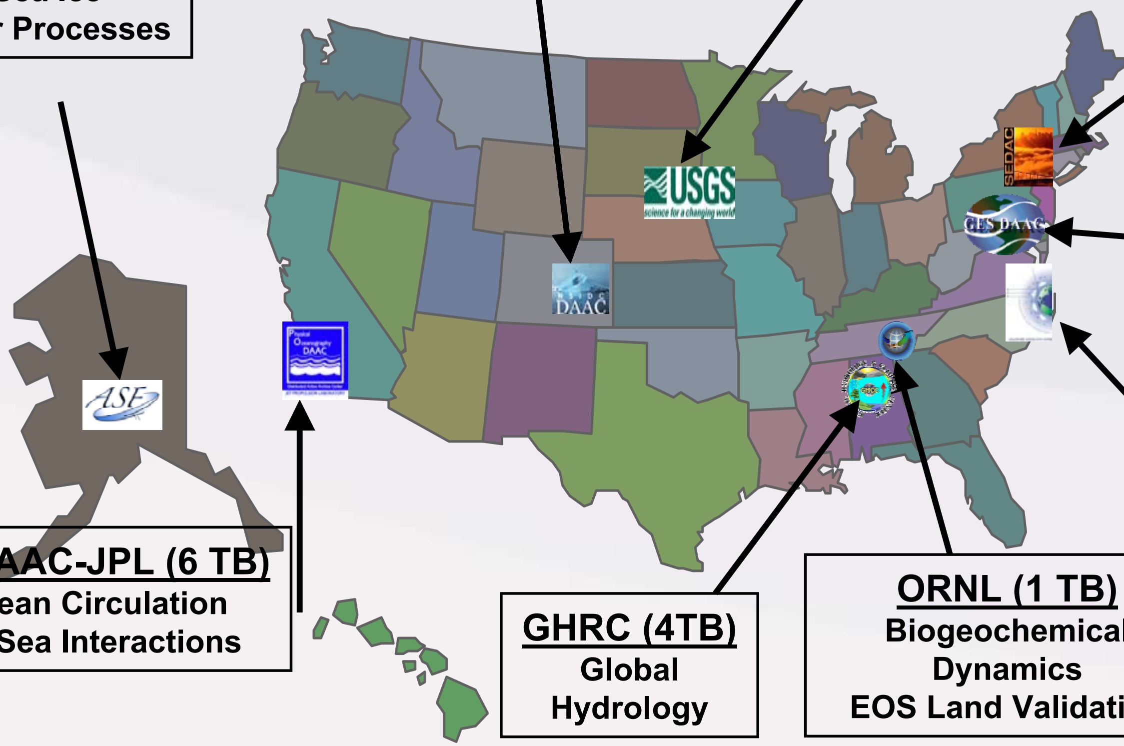
ASF (256 TB)
SAR Products
Sea Ice
Polar Processes

NSIDC (67 TB)
Cryosphere
Polar Processes

LPDAAC-EDC (1143 TB)
Land Processes
& Features

SEDAC (0.1 TB)
Human Interactions in
Global Change

GES DAAC-GSFC (1334 TB)
Upper Atmosphere
Atmospheric Dynamics, Ocean Color, Global Biosphere, Hydrology, Radiance Data



PODAAC-JPL (6 TB)
Ocean Circulation
Air-Sea Interactions

GHRC (4TB)
Global
Hydrology

ORNL (1 TB)
Biogeochemical
Dynamics
EOS Land Validation

ASDC-LaRC (340 TB)
Radiation Budget,Clouds
Aerosols, Tropospheric
Chemistry

A Broad Range of Partnerships

An inherently international endeavor

- Nearly 200 agreements with over 60 countries
- Actively engaged in international observing system planning following the July 2003 Earth Observation Summit

A variety of interagency collaborations

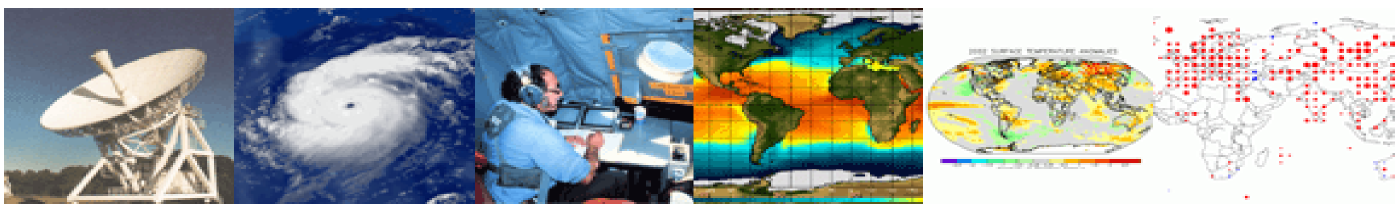
- Climate Change Science & Technology Programs
- NOAA and DoD on operational environmental satellites
- National Ocean Partnership Program & Ocean.US
- US Weather Research Program
- USGS on land remote sensing and data management
- 10 agencies on 12 National Applications

All science, applications, and technology research announcements are open competitions; about 2000 grants & contracts:

- Half won by university researchers; A quarter by NASA center scientists; A quarter by other agencies and industry scientists

GEOSS:
Global Earth Observation System of Systems

Earth Observations Summit



Observations to Users to Benefits

And the U.S. Interagency Working Group on Global Earth Observation

An international comprehensive, coordinated and sustained Earth observation system

Comprehensive: meeting the needs of a variety of science and applications disciplines

Coordinated**:** multinational satellite, suborbital and *in situ* observing capabilities strategically coordinated via agreed standards and data exchange

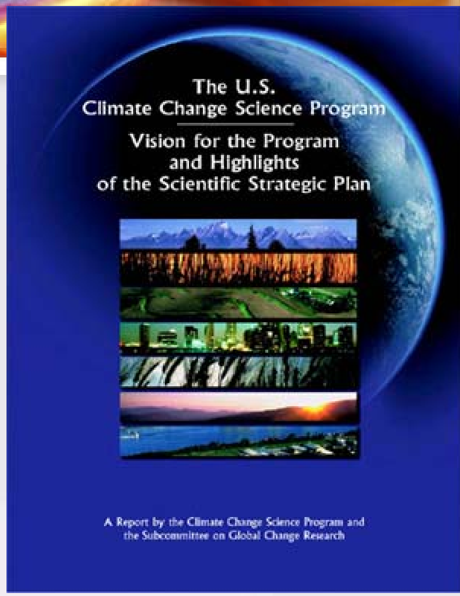
Sustained**:** long-term, continued financial and in-kind support from funding authorities

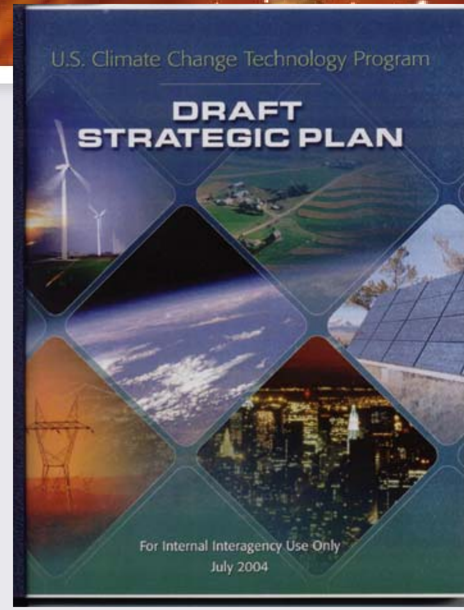
GROUP ON EARTH BSERVATIONS

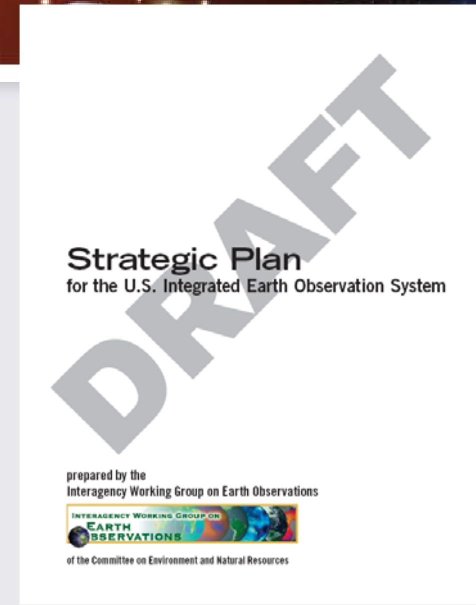
NSTC Structure

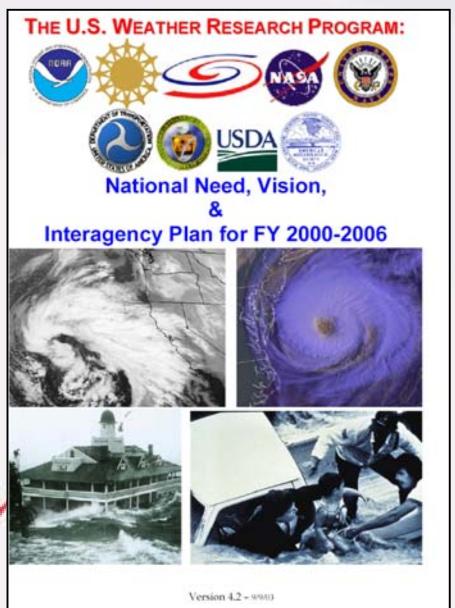
- **National Science and Technology Council**
  - Science Committee
  - Environment & Natural Resources Committee
    - Subcommittee on Global Change Research
    - Air Quality Research Subcommittee
    - Ecological Systems Subcommittee
      - Biodiversity and Ecosystem Informatics Working Group
    - Toxics & Risk Assessment Subcommittee
      - Interagency Working Group on Endocrine Disruptors
      - Interagency Working Group on Mercury
    - Subcommittee on Disaster Reduction
    - Subcommittee on Oceans (also reports to Committee on Science)
    - Subcommittee on Water Availability & Quality
    - Interagency Working Group on Earth Observations (IWGEO)
    - Subcommittee on Health and the Environment (also reports to Committee on Science and Commission on Homeland and National Security
  - Homeland & National Security Committee
  - Technology Committee

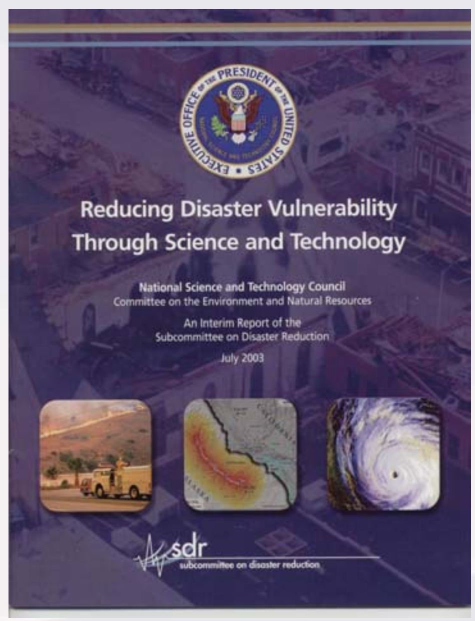
U.S. Plans for extending NASA Science Results











U.S. Commercial Remote Sensing Space Policy: Civil Agency Implementation Plan

December 12, 2003

Implementation Plan Working Group (IPWG)

The Need for a Decadal Survey

"In light of this progress, and of our recent success in securing continuity of essential EOS measurements through follow-on missions and transitions to operational satellite systems, it is time for the Earth system **science community** to look afresh into the future and help **NASA** plot its course ahead. I request that the Space Studies Board take the lead in orchestrating a decadal survey by the community to generate research and observation priorities… The resulting study will be most useful if it conveys the Earth system science **community's priorities** for questions and measurements."

From NASA's letter of October 29, 2003 to the SSB

"…look afresh into the future and help NASA chart its course ahead."

What are the significant advances in Earth system science over the past decade?

What are the principal science questions that remain to be answered?

What measurements are most critical to answering those questions?

What types of next generation observing capabilities and orbital vantage points will best enable progress?

Oct. 29, 2003 Letter of request

What opportunities are afforded by the Exploration Vision and NASA Transformation?

July 7, 2004 letter

Provisional Decadal Survey Panels

- Earth Science Applications & Societal Objectives
- Terrestrial, Coastal & Marine Ecosystems & Biodiversity
- Weather
- Climate Variability & Change
- Water Resources & the Global Hydrologic Cycle
- Human Health & Security
- Solid Earth Dynamics, Natural Hazards, and Resources

"Within this structure, some disciplines are not visible in the title of a given panel, but will have a role in several panels."

Provisional Schedule

First committee meeting	Nov 04
Town halls at AGU/AMS	Dec 04, Jan 05
Interim report	Jun 05
Initial input from panels	Jun 05
Final input from panels	Nov 05
Special sessions at AGU/AMS to discuss draft report	Dec 05, Jan 06
Final report	Jun 06

For info from the NRC, see http://qp.nas.edu/decadalsurvey

GPM Reference Concept

OBJECTIVE: Provide Enough Sampling to Reduce Uncertainty in Short-term Rainfall Accumulations. Extend Scientific and Societal Applications.

OBJECTIVE: Understand the Horizontal and Vertical Structure of Rainfall and Its Microphysical Element. Provide Training for Constellation Radiometers.

Core Satellite

- Dual Frequency Radar
- Multi-frequency Radiometer
- H2-A Launch
- TRMM-like Spacecraft
- Non-Sun Synchronous Orbit
- ~65° Inclination
- ~400 - 500 km Altitude
- ~4 km Horizontal Resolution (Maximum)
- 250 m Vertical Resolution

Constellation Satellites

- Multiple Satellites with Microwave Radiometers
- Aggregate Revisit Time, 3 Hour goal
- Sun-Synchronous Polar Orbits
- ~600 km Altitude

Global Precipitation Processing Center

- Capable of Producing Global Precip Data Products as Defined by GPM Partners

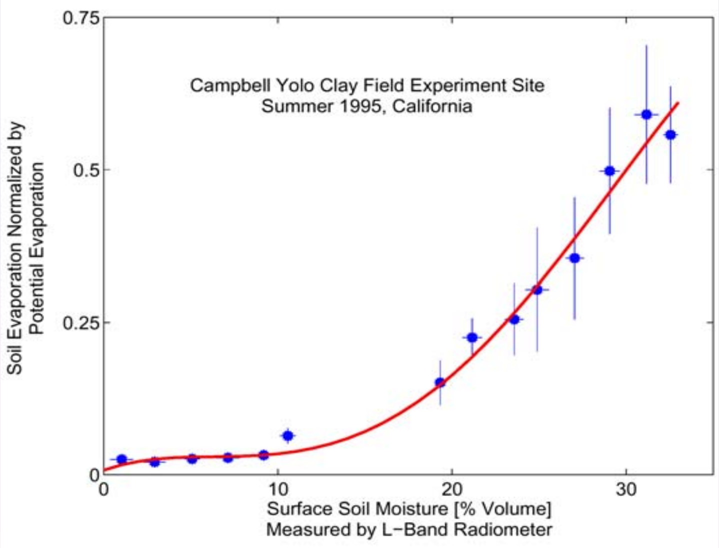
Precipitation Validation Sites

- Global Ground Based Rain Measurement

Soil Moisture - HYDROS

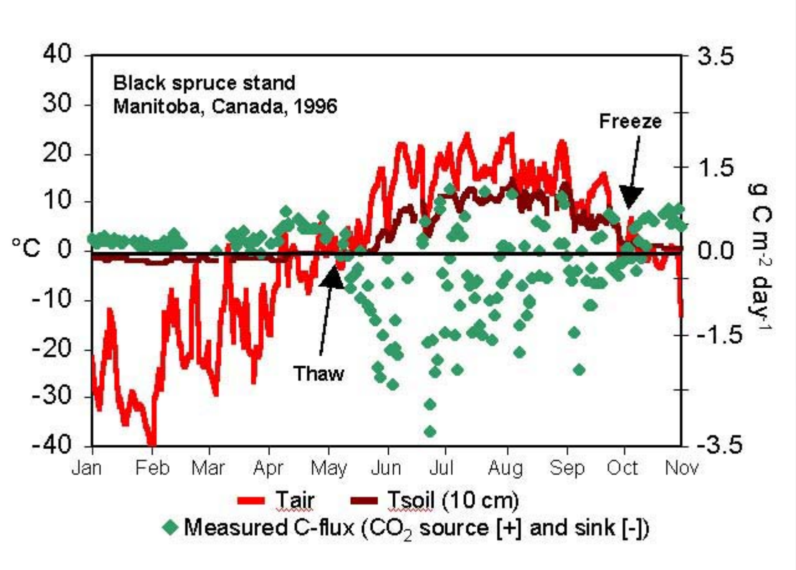
Soil Moisture a critical omission in observations suite (NASA, NOAA, USDA)

Water Cycle



Soil Moisture Strongly Influences Evaporation Rate and thus the Water and Energy Exchanges between Land & Atm.

Carbon Cycle



Freeze/Thaw Condition Influences Growing Season Length and thus the Carbon Balance.

Addresses Priority Soil Moisture Data Requirements Across Agencies

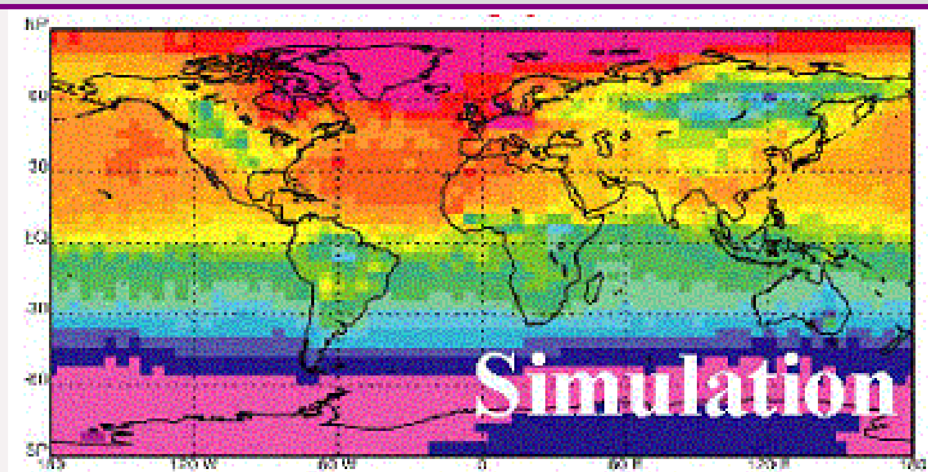
- **NASA**: Monitor Process - Global Water, Energy, and Carbon Cycles
- **NOAA**: Improve Weather and Climate Predictions: Flood and Drought
- **DoD**: Applications in All Three Services (e.g. Terrain trafficability, Fog)
- **USDA**: Agricultural Management, Drought Impact Mitigation

Orbiting Carbon Observatory (OCO)

Watching The Earth Breathe . . . Mapping CO_2 From Space

Science & Applications

- OCO will collect the first space-based measurements of atmospheric CO_2 (*Column Averaged Dry Air Mole Fraction of CO_2*) with the precision, resolution, and coverage needed to characterize carbon sources and sinks on regional scales and to quantify their variability.
- OCO measurements are needed to:
  - Identify and constrain CO_2 sources and sinks
  - Aid in balancing the global carbon budget
  - Monitor carbon management activities
  - Aid in verifying C emissions/sequestration reports



OCO Features

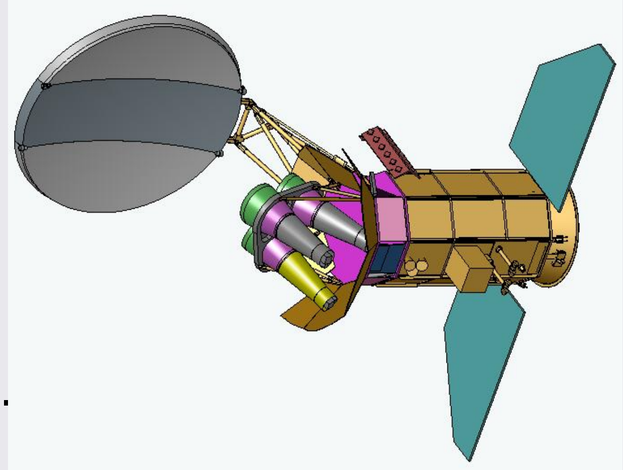
- High Resolution, 3-channel grating spectrometer
- Spacecraft flies in formation with the A-Train
- Launch date: 2007
- Operational life: 2 years
- PI: David Crisp, JPL

An ESSP Mission

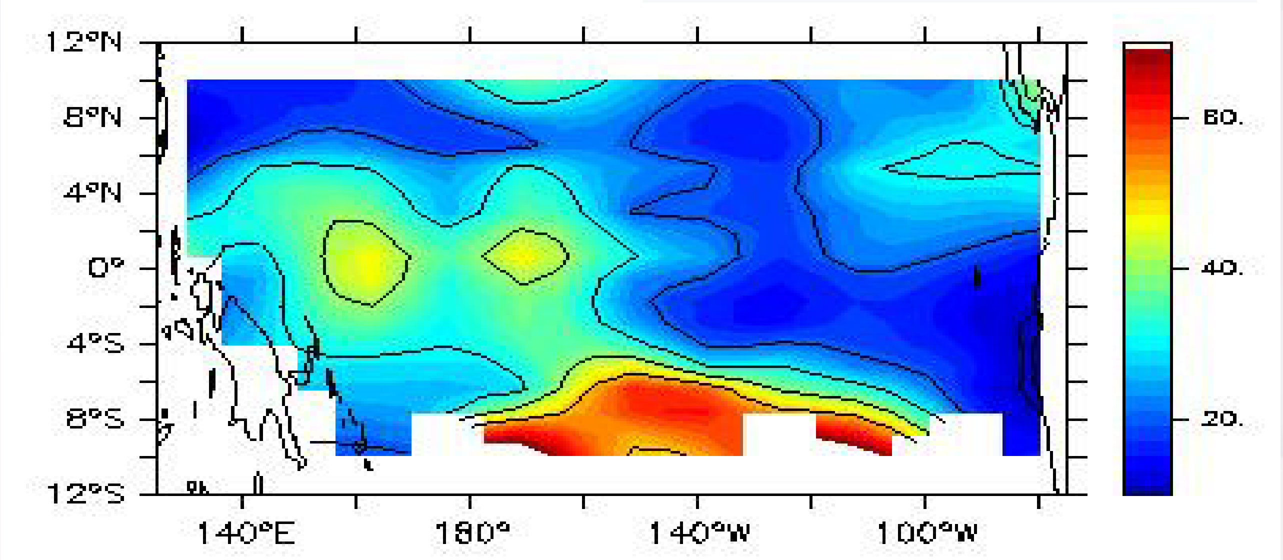
Ocean Salinity: Aquarius

Purpose: explore the variability of surface salinity in the oceans.

- Requires improved antennas, signal processing, and algorithms.
- Remotely sensed salinity data will greatly improve our knowledge of heat storage an important driver of significant climate signals.

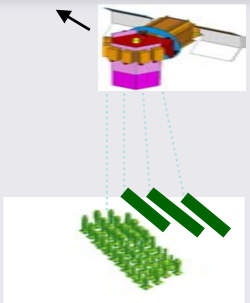


In the western tropical Pacific Ocean, the birth place of El Nino, the effect of salinity on the density and thereby ocean topography can be equal to or more than the effect of temperature.

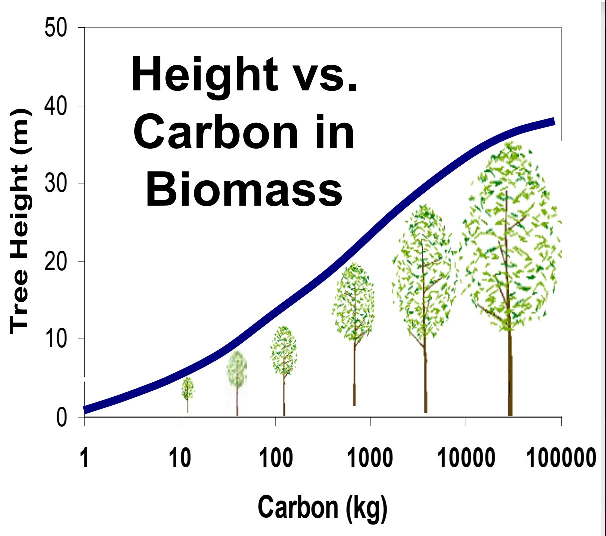


Percentage of ocean topography variability due to salinity (Maes and Behringer, 2000)

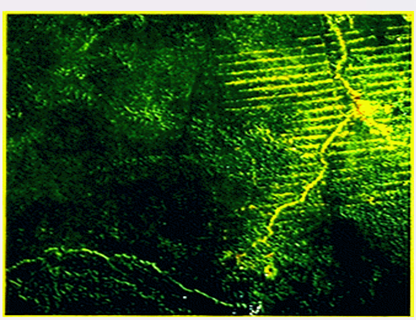
Vegetation 3-D Structure, Biomass & Disturbance

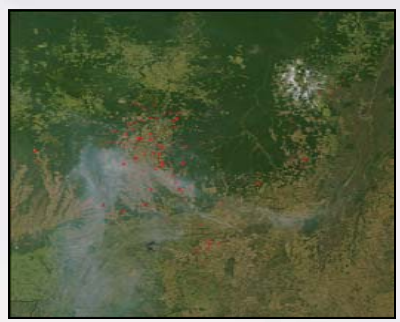


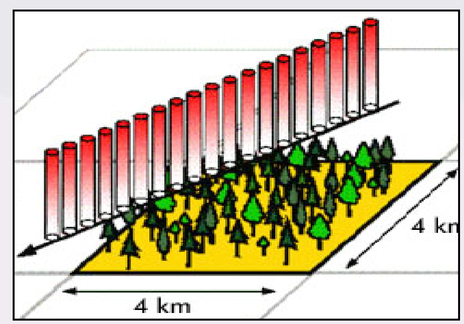
Height and/or canopy volume are used to estimate carbon in biomass (storage) in forests.



Vegetation recovery and re-growth after disturbance result in increasing carbon storage in biomass, with detectable changes in canopy 3-dimensional structure





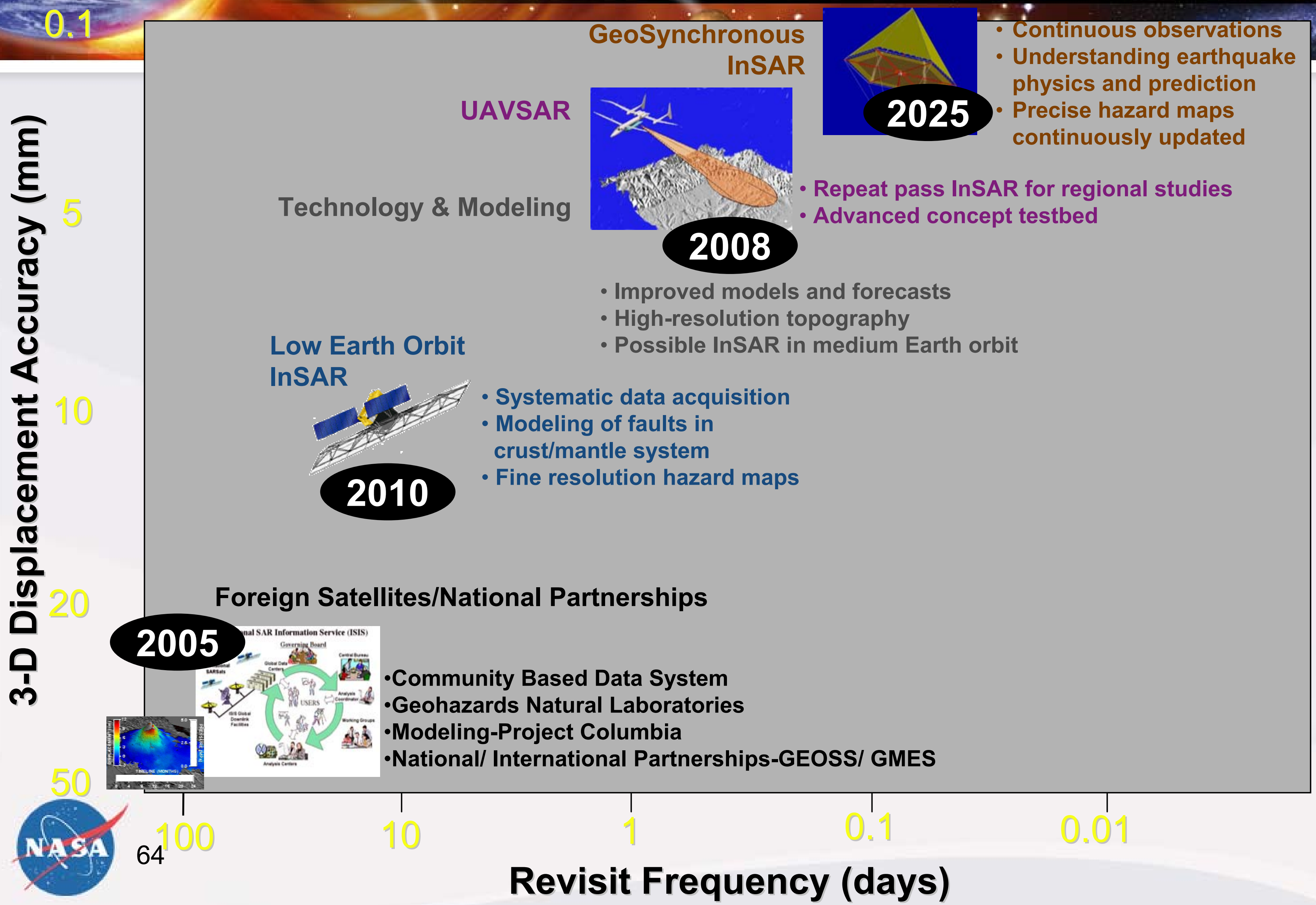


Current Capabilities Qualitative → Future Capabilities Quantitative

Landsat and MODIS sensors → Lidar, Radar, multi-angle, hyperspectral

Technology Development: Imaging lidar, L- or P-band SAR, INSAR. Laser risk reduction important!

TerraScout: A Roadmap to Understanding Surface Change



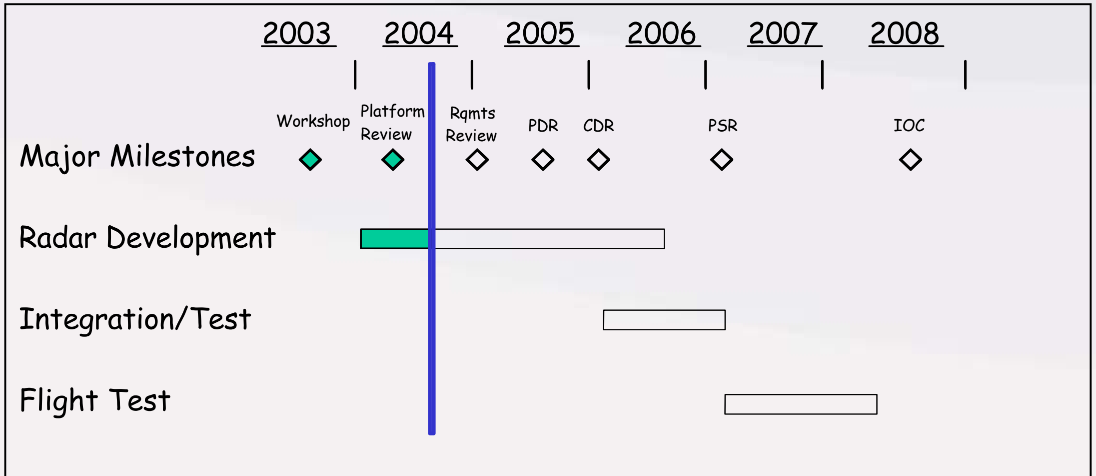
Two Baseline Systems, plus integration into a Proteus

(Single Antenna L-band Polarimetric Radars)

***Anticipated Science Applications*:**

Solid Earth
Land Cover (Classification)
Hydrology (Soil Moisture)
Agriculture
Ice (Ice Velocity)

Vegetation Structure
Hydrology (Topography)
Archeology
Cold Land Processes
Ice (Thickness and Age)
Oceanography



	2003	2004	2005	2006	2007	2008	Total
Budget ($M)	3.3	12.4	10.3	5.4	1.3		32.7

Need for Enhanced Temporal Sampling

Boston Harbor Morning

Boston Harbor Afternoon

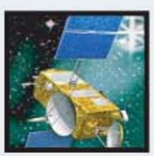
Next Generation Missions

Next Generation Missions

Candidate Future Missions
In Formulation/Preformulation

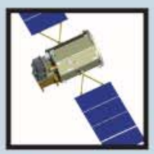
NPOESS Preparatory Project

Landsat Data Continuity Mission



Ocean Surface Topography Mission

Global Precipitation Measurement



Aerosol Polarimeter Sensor

Synthetic Aperture Radar

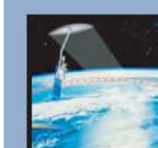
Chemistry/Climate Mission

Cryosphere Monitoring Mission

Next generation systemactic measurement missions to extend/enhance the record of science-quality global change data

Orbiting Carbon Observatory

Aquarius



Hydros

Exploratory

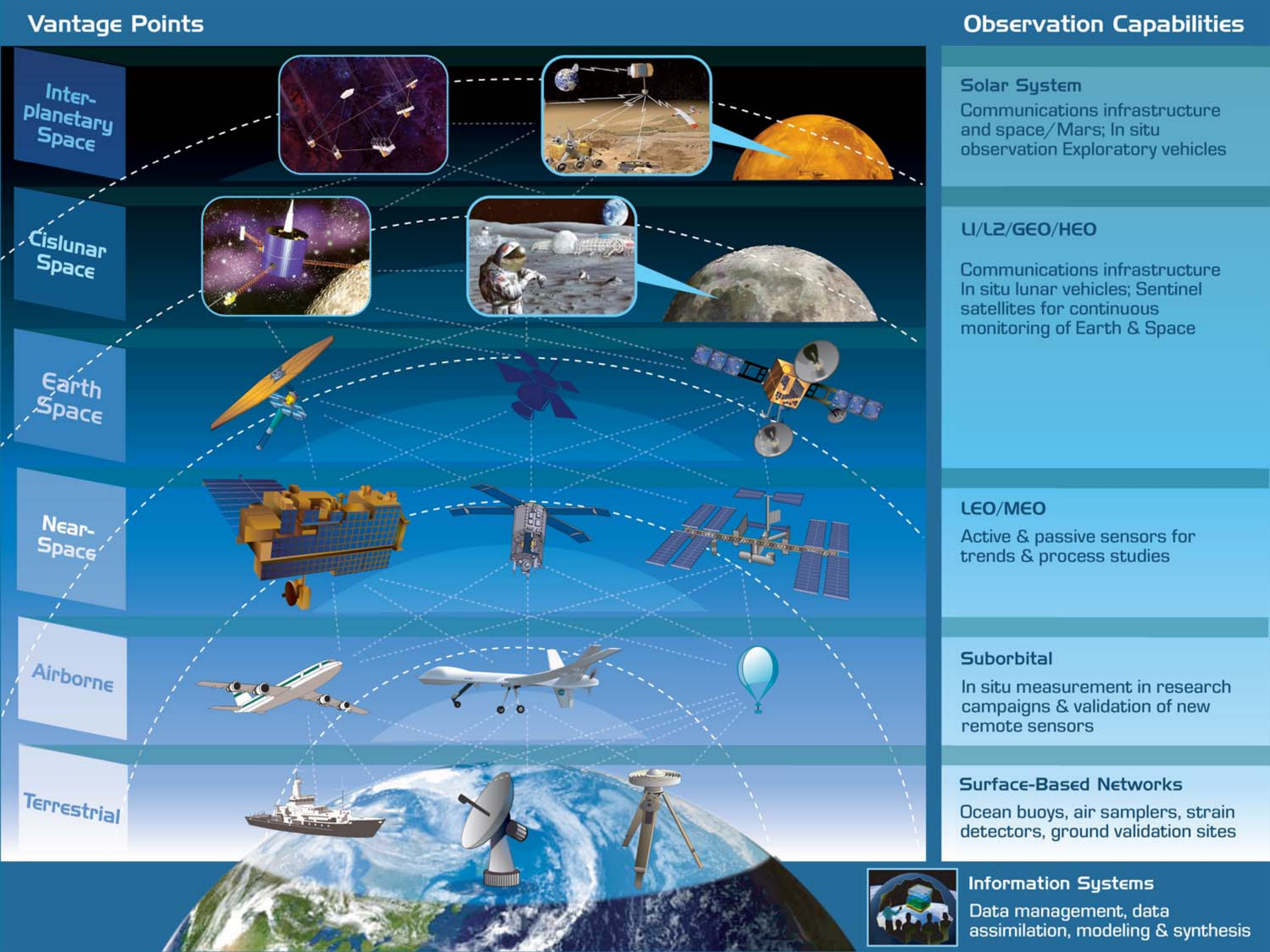
Blue Horizons

Restless Planet

Aiolos

•
•
•

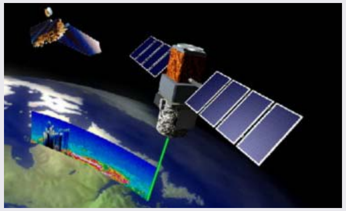
Expeditionary research missions for new vantage points & sensor types



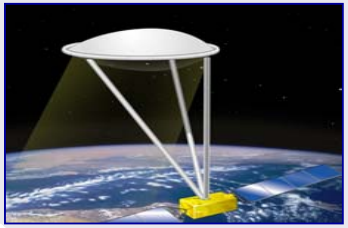
Vantage Points
Observation Capabilities
Inter-planetary Space
Cislunar Space
Earth Space
Near-Space
Airborne
Terrestrial
Solar System
Communications infrastructure and space/Mars; In situ observation Exploratory vehicles
L1/L2/GEO/HEO
Communications infrastructure In situ lunar vehicles; Sentinel satellites for continuous monitoring of Earth & Space
LEO/MEO
Active & passive sensors for trends & process studies
Suborbital
In situ measurement in research campaigns & validation of new remote sensors
Surface-Based Networks
Ocean buoys, air samplers, strain detectors, ground validation sites
Information Systems
Data management, data assimilation, modeling & synthesis

ES Technology Priorities

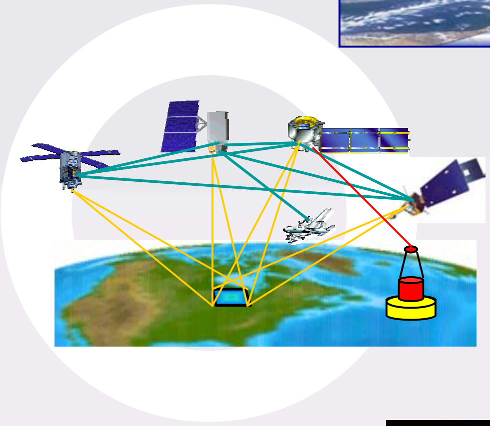
- **Active Remote Sensing Technologies** to enable atmospheric, cryospheric and earth surface measurements



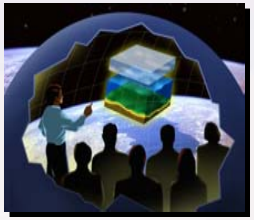
- **Large Deployables** to enable future weather/climate/ natural hazards measurements



- **Intelligent Distributed Systems** using advanced communication, on-board reprogrammable processors, autonomous network control, data compression, high density storage



- **Information Knowledge Capture** through 3-D visualization, holographic memory and seamlessly linked models.



Earth Science Strategy: Summary

In dialog with the science community, choose scientific questions for which NASA technology and remote sensing can make a defining contribution

Pursue answers to those questions via an end-to-end research program integrating technology development, Earth observation, data analysis, and data assimilation & modeling

Transition mature observation capabilities / responsibilities to operational agencies

Assist agency partners in demonstrating the utility of NASA observations and research results in those agencies' decision support systems

Envision and create the next generation of research and technology

Contribute to integrated agency scientific and exploration goals (e.g., Sun-Earth system, Earth in solar system)

Earth Science Mission: "to understand and protect our home planet by using our view from space to study the Earth system and improve prediction of Earth system change."